

Report of Electric Service Alternatives

Science, Technology and Research Campus

University of Delaware

Prepared for:

City of Newark, DE



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INTRODUCTION

Quad Three Group has been retained by the City of Newark, Delaware to investigate the most cost effective, and reliable way of serving present and future electric load growth at the former Chrysler automobile manufacturing site in the City. This site has been obtained by the University of Delaware for the purpose of establishing a Science, Technology and Research (STAR) Campus consisting of independent corporations with various expertise and product design. The overall 270 acre site divided into individual parcels is shown on an aerial photo by the University of Delaware included herein as MAP 1.

The initial study was completed and the report titled "Report of Electric Service Alternatives – Science, Technology and Research Campus – University of Delaware" was submitted on March 29, 2012 revised October 1, 2012. Since that time, the first company to locate on the site, Bloom Energy, has begun operation. Bloom Energy manufactures fuel cells, an alternate source of electric energy.

The intent of this study and report is to review assumptions that were made and revise input data based on more current information as the site develops.

The remainder of the site (220 acres) remains unspecified and unknown with regard to use and electric load requirements. For the purpose of this report we will use an estimate of 61.8 MVA for the total site electrical requirements. This is a revision to the initial study which was based on an area square foot allowance utilizing Bloom Energy as the typical site manufacturing load, adjusted for load growth. The revised site electrical requirements, although based on a square foot allowance, is based on typical office and manufacturing loads and not that of Bloom Energy. The reason that Bloom Energy is not used as a typical site load is because after it was projected to consume energy based on a 9,000 kilowatt demand, the consumption was drastically reduced and at times actually flows back into the City's system.

The fuel cells that Bloom Energy produces and sells must be tested prior to shipment. Under normal conditions, the fuel cells would have been connected to resistive load boxes and waste the energy in the form of heat. In the interest of energy conservation, the plant electrical load is now used as the test fuel cell load. The fuel cells are paralleled with the City's system and; depending on the number of fuel cells under test and the plant load, the total Bloom load can fluctuate from a 324 KVA consumer to a 1,000 KVA generator.



RECOMMENDATIONS

There are only two feasible alternatives to serve the complete build-out of the STAR Campus. Those are to install direct 34,500 volt feeders from the Kershaw Substation to the STAR Campus or install a 138,000/34,500 volt substation tapping the existing 138,000 volt transmission system that formerly served the Chrysler Facility.

The estimated cost of the direct feeders from the Kershaw Substation would be \$8,558,022. The primary reasons for this high cost is due to density and congestion to get these circuits through the center of the University of Delaware Campus. They will also have to be installed underground in two separate duct and manhole systems for reliability. Because the load is located radially at the end of the line, voltage drop is a major consideration in the design dictating that the lines be constructed with 3 – 1000MCM aluminum conductors per phase. This requires more than fifty-four miles of conductor. In addition, another feeder position will have to be added at the Kershaw Substation. There presently is only one spare feeder position.

The other alternative is to install a 138,000/34,500 volt substation in the STAR Campus tapping the existing Delmarva 138,000 volt lines. The substation would consist of two 60/80/100/112 MVA transformers, OA,FA,FA, 55°/65° C rise with seven active feeder positions. The cost of the substation would be \$8,840,600.

Although both alternatives will meet the initial criteria of supplying the complete build-out of the STAR Campus, the substation has the following additional advantages:

- Voltage Regulated Capacity is available locally within the confines of the STAR Campus.
- Even without voltage regulation, the voltage drop is well within the range required by the Public Service Commission and industry equipment operating standards whereas the other alternative meets the requirements marginally.
- The capacity of dual 60/80/100/112 MVA transformers will provide sufficient energy requirements locally with no curtailment if one source should fail. They could even back-up the complete outage of the Kershaw Substation with no interruptions to any customers.
- The 34,500 volt sub-transmission system portion of the serving facility will be totally underground. This improves system reliability from storm and vehicular damage.

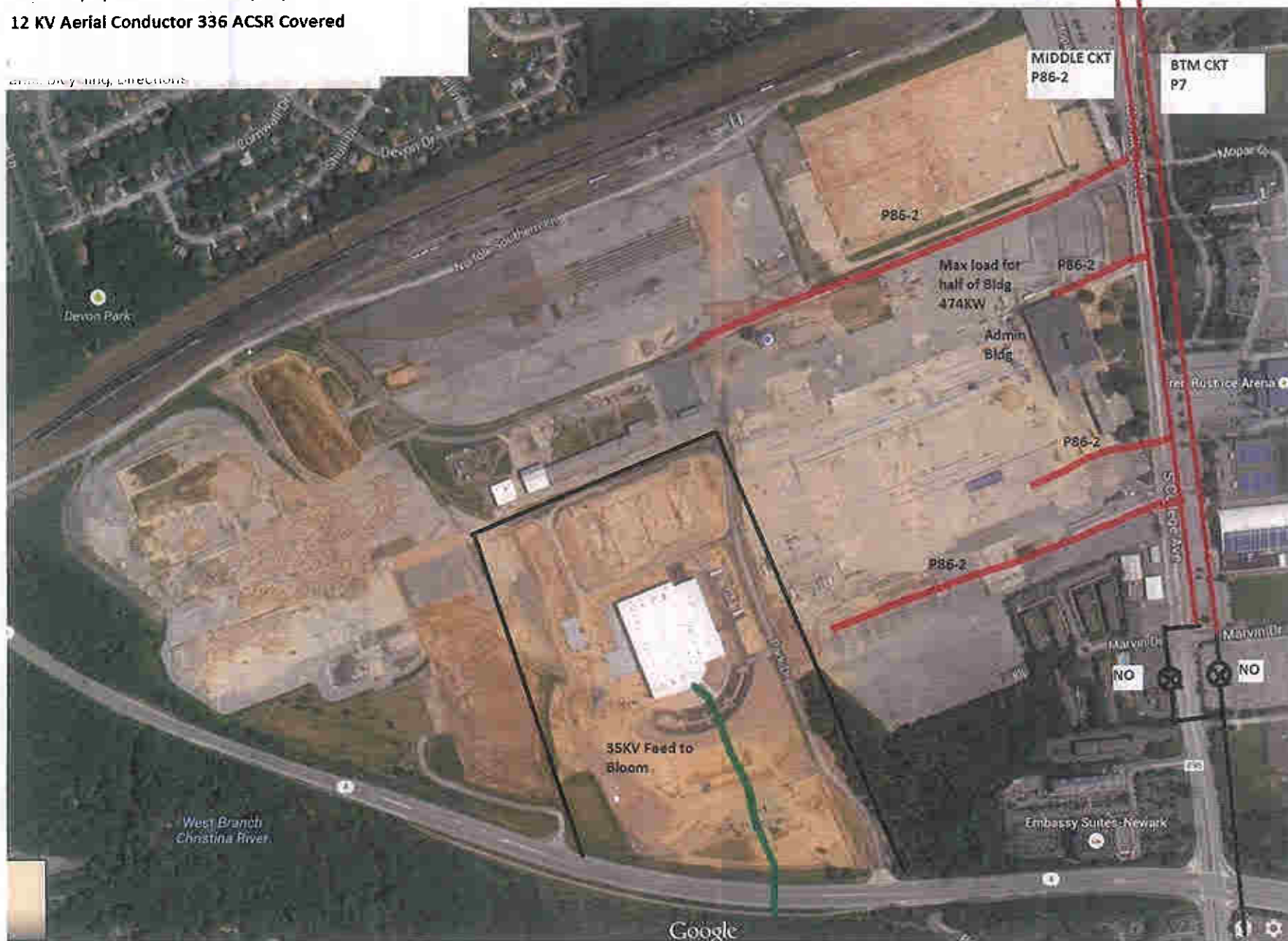


- With the interconnection of the substation to four other existing circuits, the voltage levels and feeder load levels are more manageable so that the entire southerly and southwesterly portions of the City (not only the STAR Campus) will have a much firmer energy supply than otherwise could be provided from the Kershaw Substation alone.
- This area of the City is experiencing rapid growth which is becoming extremely hard to service from the Kershaw Substation due to physical constraints of constructing intermediate interconnecting facilities.
- Emergency capacity will be relieved from normal existing feeder loading to assist in system restoration following power interruptions or maintenance outage switching requirements.
- It can supply the City's load growth well beyond the forty plus years of the transformer life expectancy and not just to the complete Campus build-out timeframe.

For these reasons, even though the substation comes at a 3.3% higher cost, it is our opinion that the additional benefits far outweigh the increased cost.

P7 5/7 MVA Transformer (1ckt)
P86-2 12/16/20 MVA Transformer (2ckt)
CHR74-2 10/12/14 MVA Transformer (2ckt)
12 KV Aerial Conductor 336 ACSR Covered

arrow pointing, directions



P86-1 Max Demand 3082 KVA
CHR74-1 Max Demand 799 KVA

Max Demand
324 KVA

CHR74-2 Max
Demand 3600 KVA

Figure: Map 1



LOAD GROWTH PROJECTIONS AT THE STAR CAMPUS

In the 2012 study and report, an estimate of 50 megawatts was projected as the electrical load requirements for the full build out of the STAR Campus. This estimate was based on the proposed consumption at the Bloom Energy Plant on a square foot basis to the remaining land area formerly occupied by the Chrysler assembly plant. Without a better knowledge of the proposed land use, it is difficult to amend that projection. We did, however, approach an estimate from a slightly different perspective and split the loading based on the building consumption from an individual light, power and HVAC basis for various building types. This resulted in an estimated total Campus load requirement of 61.8 MVA. In this analysis we used the Bloom Energy Plant size as a percentage of the Bloom site used for the building footprint. This footprint in square feet was then adjusted up or down depending on the remaining eight plot sizes. The height of each building was based on similar facilities that we are familiar with at industrial park sites and university campuses as well as one eight floor structure as a motel/hotel facility support building. This resulted in an aggregate 2,750,000 sq. ft. floor area of building structures. The electrical consumption ranged from 2,700 KVA to 10,000 KVA per building.

Because most loads will be office and manufacturing, an 85% power factor was assumed and loads were studied on a line current or MVA basis. If we were to change the 61.8 MVA to a megawatt basis, the load would be 52.53 megawatts. The 2012 study approached the load estimate from a different perspective and the load used in that study was 50 megawatts. Both approaches are, therefore, within just 5% of each other.

EXISTING ELECTRIC SERVICE FACILITIES

The former Chrysler facilities were served directly by Delmarva at 138,000 volts. There were two substations at the site which stepped the 138,000 volt transmission voltage down to the distribution level of 12,000 volts. None of this equipment in the substations could be used in conjunction with the existing City electrical system for the following reasons:

- The equipment is old, varying in age from about 18 to 44 years.
- Inefficient due to 12,000 volt supply vs. 34,500 volts. Larger wire sizes and more feeders required to supply loads.
- The City does not operate a 12,000 volt distribution system so equipment, transformers, etc. would have to be ordered and stocked separately.
- The 12,000 volt system could not be tied to the City's 12,470 volt system even if the voltages could be forced to match with transformer taps because there would be a standing phase angle of 30°.
- The substations were the property of the University, were sold and are no longer available.



There are, however, two 138,000 volt transmission lines, owned by Delmarva, in the immediate area which served these substations that could be used to serve a new substation if required.

There are two City owned and operated 34,500 volt sub-transmission lines which enter the site to serve the Bloom Energy Plant. The feeders are lines 3405 and 3406. Normal service is provided from line 3405 with line 3406 as the alternate back-up.

There is also one City owned and operated 12,470 volt distribution line which enters the Campus at four locations to serve an Administration Building and miscellaneous site requirements.

ANALYSIS OF EXISTING SERVICE FACILITIES

Service from the City of Newark's 34.5kV System: The most practical, cost effective and expedient method for supply to the Bloom Energy facility was to split the normally open 34,500 volt line which could connect feeder 3405 and feeder 3406 together between the East Chestnut Hill Substation and the Sandy Brae Substation along the Christiana Parkway. The feeders were then extended to the Bloom Energy point of service and connected to switchgear with automatic controls for transferring to the alternate circuit following a loss of the normal source. Switch 3402/23 is being operated normally closed, with line 3405 being the normal supply source to Bloom Energy and line 3406 being the alternate source of supply. These circuits originate at different busses at the Kershaw Substation so that back-up redundancy will include all of the Newark facilities. In fact, the 138,000 volt transmission lines connected to the transformers that feed these busses at the Kershaw Substation, originate from different Delmarva sources.

The Bloom Energy plant load was to start at about 3 megawatts and gradually ramp up to 9 megawatts. To date, this has not happened. The maximum load has been 324 KVA and at other times 1000 KW net supplied back into the City's system. Bloom Energy manufactures fuel cells. The fuel cells must be tested before shipment. When they are under test, instead of using load boxes that just generate heat, Bloom is supplying power back into the system as well as satisfying their own energy requirements as a load for these fuel cells. This will reduce the load originally projected under normal system conditions, when the Bloom Energy load is being supplied from line 3405 in conjunction with the other line 3405 loads, to about 9.5 MVA (159 amperes).



Line 3405 is also the backup supply facility to line 3414 which is the normal feed to other University of Delaware loads. This future peak load is projected to be 13.5 MVA. Even if the UD load is transferred to line 3405 with line 3414 out of service, the peak coincident load on line 3405 will only be approximately 23.0 MVA (385 amperes) under the revised Bloom load requirements.

Under the present Bloom load requirements, the alternate feed (Line 3406) will have a peak coincident load of 14.3 MVA (239 amperes) when the Bloom Energy load is transferred to it.

All of these loads are within the capability of the supply facilities and voltage drops are less than one half of what is allowed by the Public Service Commission and industry connected equipment standards.

Service from the City of Newark's 12.47kV System: 12,470 volt distribution lines from the Phillips Avenue Substation, feeder P86-2 were run into the site to serve the Administration Building and other miscellaneous loads for several reasons:

- The Administration Building borders the STAR Campus property line along South College Ave. where the existing 12,470 volt feeder is located making it an expedient and economical interim connection.
- The maximum load for half of the building is only 474 KW. Assuming the total load for both halves to be about 1000 KW, the load is manageable at 12,470 volts.
- Running 12,470 volt distribution for small site loads is more economical than running sub-transmission at 34,500 volts.
- Using the Bloom 34,500 volt circuits would have required extending them over half way across the Campus. The original load projections for Bloom would have made the loading on these feeders marginal under emergency conditions.

Although this development of 12,470 volts is warranted for these particular loads, existing substation capacity is not available to serve an assumed future site load of 61.8 MVA without adding additional 34,500/12,470 volt transformer capacity to the Newark system. This in turn would load down the supplying 34,500 volt system to these new transformers and would necessitate adding additional 34,500 volt lines to this area to serve on-site as well as off-site loads through the stressed 12,470 and 4,160 volt distribution facilities.



Extending direct 34,500 volt feeders from Kershaw Substation: The extension of the 34,500 volt sub-transmission system to serve the entire STAR Campus eliminates the 34,500/12,470 volt substations and requires less 34,500 volt feeders than those required to serve the Campus at 12,470 volts. The problem of physically getting additional 34,500 volt feeders from the Kershaw Substation to the STAR Campus, however, will remain an issue. Physical congestion near the Kershaw Substation and along potential routes in the direction of the STAR Campus makes the supply at 34,500 volts from the Kershaw Substation extremely critical for the routing of future site load requirements. There presently is only one spare 34,500 volt feeder position remaining at the Kershaw Substation. To get two circuits from Kershaw, another feeder position will have to be established in conjunction with the existing spare.

The extension of the City's 12,470 volt distribution system to serve the entire STAR Campus adds equipment costs by requiring additional 34,500/12,470 volt substations, more additional 12,470 volt feeders than would otherwise be required to serve the same load at 34,500 volts and additional 34,500 volt sub-transmission feeders to serve the required additional substations.

In fact, heavy loading anticipated at the STAR Campus as well as heavy loading served by the Sandy Brae, East Chestnut Hill Road, South Chapel Street and Phillips Avenue Substations are occurring in the opposite direction from the 138,000/34,500 volt Kershaw Substation. Severe physical congestion in the downtown Newark area through the center of the University of Delaware Campus makes the installation of future new circuits between the areas of heaviest load expansion and the source at the Kershaw Substation nearly impossible to construct.

Heavy load cycling near the ends of feeders also exaggerates voltage drops to the point of making otherwise small variations extremely perceptible. It also limits the ability to adequately provide back-up from adjacent feeders.

Service from a new 138,000/34,500 volt Substation: Considering these factors, constructing a 138,000/34,500 volt substation in the vicinity of the STAR Campus seems to have a high degree of merit. This conclusion was also reached in the study and report completed in 2012. The main emphasis of the remainder of this report will compare a proposed 138,000/34,500 volt STAR Campus Substation service option to a proposed direct service at 34,500 volts from the Kershaw Substation option from an engineering, reliability and cost standpoint.



LOAD FLOW AND VOLTAGE DROP STUDIES

Load flow and voltage drop studies were performed for various system contingencies. Since the Newark system is operated as a normally radial system, all studies were performed at the substation and 34,500 volt feeders on a coincident peak load basis. For this reason no diversity was assumed and the total system peak load is in excess of that actually recorded at the Kershaw Substation. Since we are not concerned with the loading on the Kershaw transformers due to available capacity, this approach is appropriate since we only care what the peak loading on the 34,500 volt feeders and 34,500 volt step down substations are. The 2014 maximum Base Case study was run under present loading and operating conditions. This study is presented in Appendix I.

The largest uncorrected voltage drop is at the Phillips Avenue Substation with a magnitude of 3.29% and the heaviest loaded line is Feeder 3413 at 95.9% of rating.

Appendix II is the Base Case study with the STAR Campus completely developed and loaded to 61.8 MVA. This scenario was run with no additional capacity to the STAR Campus to reinforce the existing Feeders 3405 and 3406. This scenario destroys the system wide voltage levels as shown below and drives feeder loading to wire burn down levels.

<u>Load</u>	<u>Voltage Drop</u>
STAR Campus Loads served from Feeder 3406	-19.24%
Sandy Brae Substation	-16.50%
STAR Campus Loads served from Feeder 3405	-11.45%
Phillips Avenue Substation	-11.08%
East Chestnut Hill Road Substation	-9.75%
East Main Street Substation	-9.65%
South Chapel Street Substation	-8.91%
Wyoming Road Substation	-6.63%
West Main Street Substation	-5.27%

The heaviest feeder loading is Feeder 3406 at 216% of rating. Needless to say, there is no capacity backup for any 34.5kV feeder.

The next scenario is shown in Appendix III and is the same loading as Appendix II but with two express feeders from the Kershaw Substation to the STAR Campus. This improves the voltage levels overall, but voltage drops remain in the 4.42% to 7.35% uncorrected area. The lowest is West Main Street Substation at 7.35%. The heaviest loaded feeder is 3411 at 100.6% of maximum rating. The two new



circuits to the STAR Campus can back each other up with regard to capacity but the voltage drop with one circuit out of service is in the area of 9% to 10% which is at the threshold of intolerable voltage levels. The circuits, assuming underground for the entire route, would consist of 3-1000MCM aluminum conductors per phase. To assure backup reliability, both circuits would have to be in separate duct and manhole systems to prevent the loss of both circuits following a fault and manhole fire.

Although this scenario will work, it has some system equipment operating with no excess capacity and marginal voltage levels. This design will also not help loadings on existing 34,500 volt feeders in the area outside of the STAR Campus.

The final scenario is Appendix IV which assumes the same loading, but includes a double ended 138,000/34,500 volt substation at the STAR Campus complex for capacity support. The voltage drops range from 0.74% to 2.57%. The 2.57% drop is at the Sandy Brae Substation. The maximum feeder loading is 76.5% on the 3404 Feeder. The loading on all other feeders are backed off dramatically due to additional 34,500 volt lines from the STAR Campus Substation connecting to the existing Newark System. These feeders connect to those feeding the Sandy Brae Substation, Phillips Avenue Substation, the Wyoming Road Substation and the East Chestnut Hill Rd. Substation.

This greatly improves system reliability by providing an additional four sources to the current Newark System as well as providing local sources to the STAR Campus. By reducing existing feeder loading, emergency feeder capacity is available for switching during power outages and load pick-up for maintenance outage switching.

There is no doubt that a double ended 138,000/34,500 volt substation is the best solution from an engineering and reliability standpoint for the following reasons:

- Voltage Regulated Capacity is available locally within the confines of the STAR Campus.
- Even without voltage regulation, the voltage drop is well within the range required by the Public Service Commission and industry equipment operating standards.
- The capacity of dual 60/80/100/112 MVA transformers will provide sufficient energy requirements locally with no curtailment if one source should fail.
- The 34,500 volt sub-transmission system portion of the serving facility will be totally underground. This improves system reliability from storm and vehicular damage.



- With the interconnection of the substation to four other existing circuits, the voltage levels and feeder load levels are more manageable so that the entire southerly and southwesterly portions of the City will have a much firmer energy supply than otherwise could be provided from the Kershaw Substation alone.
- This area of the City is experiencing rapid growth which is becoming extremely hard to service from the Kershaw Substation due to physical constraints of constructing intermediate interconnecting facilities.
- Emergency capacity will be relieved from normal existing feeder loading to assist in system restoration following power interruptions or maintenance outage switching requirements.

COST ESTIMATE COMPARISONS

The cost estimate for the proposed routing of two new 34,500 volt sub transmission lines completely underground from the Kershaw Substation to the STAR Campus is shown in Appendix V at \$8,558,022. Due to congestion and reliability, undergrounding of these source lines is required. An additional circuit breaker position will also be required at the Kershaw Substation because only one spare position currently exists.

The cost estimate for a double ended substation consisting of two 138,000/34,500 volt, 60/80/100/112 MVA. OA,FA,FA, 55°/65°C transformers, seven active feeders, two low side bank circuit breakers and one tie circuit breaker is shown in Appendix VI at \$8,840,600.

The substation estimate is \$282,578 or 3.3% more than the 34,500 volt feeder estimate. However, there is one important issue that should be considered beyond those outlined above from an engineering and reliability point-of-view. That issue is the fact that the two 34,500 volt feeder option is just sufficient to get past the immediate build-out of the STAR Campus. The substation option has the capability of supplying future load growth well beyond the forty plus year life expectancy of the transformers.

Utilities are becoming potential terroristic targets for catastrophic shutdowns of our economy and way of life. Transformers in particular, because they are not a stock item in the sizes you have installed and are exceptionally long lead time items, make your substation extremely vulnerable as a potential target. I say substation because without a back-up, the Kershaw Substation is it. We are involved with municipal electric utilities currently planning for the complete destruction of any substation they have and still remain as a functioning utility capable of serving all of their customers. Municipal systems are more susceptible to extended downtime because they do not have the ability to switch out major substations and operate on remote substations from another city or area or install mobile substations as an investor owned utility can.

Appendix I

Project: Base Case Maximum 2014 Loads
Scenario: Base Case

Load Flow Summary Report

Load Flow Study Settings

Include Source Impedance	Yes	Load Acceleration Factor	1.00
Solution Method	Exact (Iterative)	Bus Voltage Drop %	5.00
Load Specification	Connected Load	Branch Voltage Drop %	3.00
Generation Acceleration Factor	1.00		

Swing Generators

Source	In/Out Service	Vpu	Angle	kW	kvar	VD%	Utility Impedance
Delmarva	In	1.00	0.00	111,686.2	59,715.9	2.84	0.01 +j 0.03
UTIL-0003	In	1.00	0.00	0.0	0.0	0.00	0.01 +j 0.03

Buses

Bus Name	In/Out Service	Design Volts	LF Volts	Angle Degree	PU Volts	%VD
138 kV Bus	In	138,000	134,078	-2.07	0.97	2.84
34.5 kV Bus 3	In	34,500	34,238	-33.89	0.99	0.76
34.5 kV Bus 4	In	34,500	34,049	-35.28	0.99	1.31
34.5 kV Bus 5	In	34,500	34,185	-34.58	0.99	0.91
BUS-0017	In	34,500	33,980	-34.45	0.98	1.51
BUS-0049	In	34,500	34,181	-34.05	0.99	0.92
BUS-0055	In	34,500	33,777	-35.15	0.98	2.10
BUS-0060	In	138,000	138,000	0.00	1.00	0.00
E. Chestnuthill Hill Rd.	In	34,500	33,924	-34.54	0.98	1.67
E. Main St.	In	34,500	33,818	-35.58	0.98	1.98
Fremont Rd. Sub	In	34,500	33,702	-35.27	0.98	2.31
Phillips Ave. Sub	In	34,500	33,366	-36.20	0.97	3.29
S. Chapel St.	In	34,500	33,969	-34.45	0.98	1.54
Sandy Brae Sub	In	34,500	33,727	-36.45	0.98	2.24
STAR Campus Bus 1	In	34,500	33,727	-36.45	0.98	2.24
STAR Campus Bus 2	In	34,500	33,917	-34.55	0.98	1.69
University of Delaware	In	34,500	34,104	-34.84	0.99	1.15
W. Main St.	In	34,500	33,489	-35.54	0.97	2.93

Bus Name	In/Out Service	Design Volts	LF Volts	Angle Degree	PU Volts	%VD
Wyoming Rd.	In	34,500	33,806	-34.47	0.98	2.01

Cables

From Bus To Bus	Component Name	In/Out Service	%VD	kW Loss	kvar Loss	kVA Loss	LF Amps Rating %	PF
34.5 kV Bus 3 BUS-0012	CBL-0005	In	0.01	8,738.3 0.4	3,407.6 0.6	9,379.2 0.8	158.2 16.2	0.93
34.5 kV Bus 3 BUS-0050	CBL-0014	In	0.03	18,391.4 4.6	11,650.9 6.5	21,771.2 7.9	367.1 75.2	0.84
34.5 kV Bus 4 BUS-0007	CBL-0002	In	0.01	14,048.2 1.1	1,532.3 1.5	14,131.5 1.9	239.6 49.1	0.99
34.5 kV Bus 4 BUS-0038	CBL-0013	In	0.05	18,765.4 7.5	11,764.9 10.6	22,148.4 13.0	375.6 76.9	0.85
34.5 kV Bus 5 BUS-0031	CBL-0010	In	0.07	23,730.5 13.0	14,355.4 18.4	27,734.7 22.5	468.4 95.9	0.86
34.5 kV Bus 5 BUS-0033	CBL-0011	In	0.07	13,472.1 8.1	1,267.4 11.5	13,531.6 14.1	228.5 46.8	1.00
BUS-0008 Sandy Brae Sub	CBL-0003	In	0.01	13,945.1 1.1	1,247.5 1.6	14,000.8 1.9	239.6 49.1	1.00
BUS-0014 University of Delaware	CBL-0006	In	0.00	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.00

From Bus To Bus	Component Name	In/Out Service	%VD	kW Loss	kvar Loss	kVA Loss	LF Amps Rating %	PF
BUS-0017	CBL-0008	In	0.00	2,391.2	214.7	2,400.8	40.8	1.00
BUS-0021				0.1	0.1	0.1	8.4	
BUS-0021	CBL-0009	In	0.03	2,391.1	214.6	2,400.7	40.8	1.00
S. Chapel St.				0.7	0.2	0.7	28.3	
BUS-0053	CBL-0015	In	0.05	14,200.5	8,805.1	16,708.8	289.0	0.85
Phillips Ave. Sub				5.5	7.8	9.6	59.2	
BUS-0054	CBL-0007	In	0.03	8,731.6	3,377.9	9,362.3	158.2	0.93
BUS-0016				2.1	3.0	3.7	32.4	
BUS-0062	CBL-0017	In	0.00	0.0	0.0	0.0	0.0	0.00
STAR Campus Bus 1				0.0	0.0	0.0	0.0	
Phillips Ave. Sub	CBL-0016	In	0.00	0.0	0.0	0.0	0.0	0.00
STAR Campus Bus 1				0.0	0.0	0.0	0.0	
Sandy Brae Sub	CBL-0004	In	0.00	0.0	-5.1	5.1	0.1	0.00
BUS-0010				0.0	0.0	0.0	0.0	
STAR Campus Bus 2	CBL-0019	In	0.00	-278.2	-168.0	325.0	5.5	0.86
BUS-0064				0.0	0.0	0.0	1.1	
STAR Campus Bus 2	CBL-0020	In	0.00	0.0	0.0	0.0	0.0	0.00
Wyoming Rd.				0.0	0.0	0.0	0.0	

2-Winding Transformers

From Bus To Bus	Component Name	In/Out Service	%VD	kW Loss	kvar Loss	kVA Loss	LF Amps Rating %	PF
138 kV Bus	T3	In	-2.08	27,165.5	16,227.4	31,643.2	136.0	0.86
34.5 kV Bus 3				35.9	1,168.9	1,169.5	32.6	
138 kV Bus	T4	In	-1.53	47,257.2	25,882.9	53,881.0	232.0	0.88
34.5 kV Bus 4				104.1	3,389.1	3,390.7	55.5	
138 kV Bus	T5	In	-1.93	37,263.5	17,605.6	41,213.2	177.0	0.90
34.5 kV Bus 5				60.9	1,982.8	1,983.8	42.4	
BUS-0060	XF2-0004	In	0.00	0.0	0.0	0.0	0.0	0.00
STAR Campus Bus 1				0.0	0.0	0.0	0.0	
BUS-0060	XF2-0005	In	0.00	0.0	0.0	0.0	0.0	0.00
STAR Campus Bus 2				0.0	0.0	0.0	0.0	

Pi Impedances

From Bus To Bus	Component Name	%VD	kW Loss	kvar Loss	kVA Loss	LF Amps Rating %	PF
STAR Campus Bu STAR Campus Bu	PI-0010	0.00	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.00
34.5 kV Bus 4 34.5 kV Bus 3	Tie Bus 3 to 4	0.00	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.00
34.5 kV Bus 5 34.5 kV Bus 4	Tie Bus 4 to 5	0.00	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.00
34.5 kV Bus 5 34.5 kV Bus 3	Tie Bus 5 to 3	0.00	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.00

Transmission Lines

From Bus To Bus	Component Name	%VD	kW Loss	kvar Loss	kVA Loss	LF Amps Rating %	PF
BUS-0007	XLN-0001	0.91	14,047.1	1,530.8	14,130.3	239.6	0.99
BUS-0008			102.0	283.3	301.1	0.0	
BUS-0010	XLN-0002	0.00	0.0	-5.1	5.1	0.1	0.00
BUS-0062			0.0	-5.1	5.1	0.0	
BUS-0012	XLN-0003	0.16	8,737.8	3,407.0	9,378.5	158.2	0.93
BUS-0049			4.6	26.2	26.6	0.0	
BUS-0049	XLN-0004	0.00	0.0	-1.3	1.3	0.0	0.00
BUS-0014			0.0	-1.3	1.3	0.0	
BUS-0016	XLN-0005	0.52	8,729.5	3,374.9	9,359.2	158.2	0.93
BUS-0017			24.8	64.6	69.2	0.0	
BUS-0017	XLN-0006	0.16	6,313.6	3,095.6	7,031.6	119.5	0.90
E. Chestnuthill Hill Rc			5.3	12.8	13.8	0.0	
BUS-0064	XLN-0007	0.02	-278.2	-168.0	325.0	5.5	0.86
E. Chestnuthill Hill Rc			0.0	-5.7	5.7	0.0	
BUS-0031	XLN-0008	1.11	23,717.5	14,337.0	27,714.1	468.4	0.86
BUS-0055			132.1	379.1	401.5	0.0	
BUS-0033	XLN-0009	0.17	13,463.9	1,255.8	13,522.4	228.5	1.00
University of Delawar			17.9	49.6	52.7	0.0	
34.5 kV Bus 4	XLN-0010	1.93	14,339.5	9,196.6	17,035.2	288.9	0.84
BUS-0053			139.0	391.5	415.4	0.0	
BUS-0038	XLN-0012	0.62	18,757.9	11,754.4	22,136.5	375.6	0.85
E. Main St.			57.9	165.1	175.0	0.0	
BUS-0050	XLN-0013	1.22	18,386.8	11,644.4	21,763.9	367.1	0.84
Wyoming Rd.			111.8	318.5	337.6	0.0	

From Bus To Bus	Component Name	%VD	kW Loss	kvar Loss	kVA Loss	LF Amps Rating %	PF
BUS-0049	XLN-0014	0.03	8,733.2	3,382.0	9,365.2	158.2	0.93
BUS-0054			1.6	4.1	4.4	0.0	
BUS-0055	XLN-0015	0.22	6,172.0	3,002.6	6,863.6	117.3	0.90
Fremont Rd. Sub			7.0	16.7	18.1	0.0	
BUS-0055	XLN-0016	0.83	17,413.4	10,955.3	20,572.9	351.7	0.85
W. Main St.			73.4	208.9	221.4	0.0	

Appendix II

Project: Base Case with Max. STAR Campus Buildout
Scenario: Srvd from Feeders 3405 & 3406

Load Flow Summary Report

Load Flow Study Settings

Include Source Impedance	Yes	Load Acceleration Factor	1.00
Solution Method	Exact (Iterative)	Bus Voltage Drop %	5.00
Load Specification	Connected Load	Branch Voltage Drop %	3.00
Generation Acceleration Factor	1.00		

Swing Generators

Source	In/Out Service	Vpu	Angle	kW	kvar	VD%	Utility Impedance
Delmarva	In	1.00	0.00	164,807.2	119,562.9	5.50	0.01 +j 0.03
UTIL-0003	In	1.00	0.00	0.0	0.0	0.00	0.01 -j 0.03

Buses

Bus Name	In/Out Service	Design Volts	LF Volts	Angle Degree	PU Volts	%VD
138 kV Bus	In	138,000	130,408	-3.04	0.94	5.50
34.5 kV Bus 3	In	34,500	32,666	-36.38	0.95	5.32
34.5 kV Bus 4	In	34,500	31,421	-39.14	0.91	8.93
34.5 kV Bus 5	In	34,500	33,393	-35.70	0.97	3.21
BUS-0017	In	34,500	31,438	-38.15	0.91	8.88
BUS-0049	In	34,500	32,374	-36.91	0.94	6.16
BUS-0055	In	34,500	32,975	-36.29	0.96	4.42
BUS-0060	In	138,000	138,000	0.00	1.00	0.00
E. Chestnuthill Hill Rd.	In	34,500	31,137	-38.55	0.90	9.75
E. Main St.	In	34,500	31,170	-39.50	0.90	9.65
Fremont Rd. Sub	In	34,500	32,899	-36.42	0.95	4.64
Phillips Ave. Sub	In	34,500	30,677	-40.22	0.89	11.08
S. Chapel St.	In	34,500	31,425	-38.16	0.91	8.91
Sandy Brae Sub	In	34,500	28,809	-43.17	0.84	16.50
STAR Campus Bus 1	In	34,500	27,863	-44.36	0.81	19.24
STAR Campus Bus 2	In	34,500	30,550	-39.23	0.89	11.45
University of Delaware	In	34,500	33,311	-35.97	0.97	3.45
W. Main St.	In	34,500	32,681	-36.70	0.95	5.27

Bus Name	In/Out Service	Design Volts	LF Volts	Angle Degree	PU Volts	%VD
Wyoming Rd.	In	34,500	32,213	-37.02	0.93	6.63

Cables

From Bus To Bus	Component Name	In/Out Service	%VD	kW Loss	kvar Loss	kVA Loss	LF Amps Rating %	PF
34.5 kV Bus 3 BUS-0012	CBL-0005	In	0.03	27,722.6 6.4	19,357.0 9.0	33,811.7 11.1	597.6 61.2	0.82
34.5 kV Bus 3 BUS-0050	CBL-0014	In	0.04	18,403.2 5.1	11,685.0 7.1	21,799.5 8.8	385.3 78.9	0.84
34.5 kV Bus 4 BUS-0007	CBL-0002	In	0.05	47,712.4 21.1	31,894.6 29.8	57,391.1 36.5	1,054.6 216.0	0.83
34.5 kV Bus 4 BUS-0038	CBL-0013	In	0.06	18,777.0 8.8	11,797.0 12.4	22,175.3 15.2	407.5 83.5	0.85
34.5 kV Bus 5 BUS-0031	CBL-0010	In	0.08	23,741.8 13.7	14,387.7 19.3	27,761.1 23.7	480.0 98.3	0.86
34.5 kV Bus 5 BUS-0033	CBL-0011	In	0.07	13,473.3 8.5	1,270.5 12.1	13,533.1 14.8	234.0 47.9	1.00
BUS-0008 Sandy Brae Sub	CBL-0003	In	0.05	45,715.3 21.5	26,137.5 30.4	52,659.8 37.2	1,054.7 216.0	0.87
BUS-0014 University of Delaware	CBL-0006	In	0.00	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.00

From Bus To Bus	Component Name	In/Out Service	%VD	kW Loss	kvar Loss	kVA Loss	LF Amps Rating %	PF
BUS-0017	CBL-0008	In	0.00	2,391.3	214.7	2,400.9	44.1	1.00
BUS-0021				0.1	0.1	0.1	9.0	
BUS-0021	CBL-0009	In	0.03	2,391.2	214.6	2,400.9	44.1	1.00
S. Chapel St.				0.8	0.2	0.9	30.6	
BUS-0053	CBL-0015	In	0.06	14,201.6	8,806.5	16,710.5	314.3	0.85
Phillips Ave. Sub				6.6	9.3	11.4	64.4	
BUS-0054	CBL-0007	In	0.14	27,628.1	18,866.9	33,455.6	597.6	0.83
BUS-0016				30.5	43.1	52.8	122.4	
BUS-0062	CBL-0017	In	0.23	31,268.8	23,497.3	39,113.4	808.1	0.80
STAR Campus Bus 1				68.8	97.3	119.1	165.5	
Phillips Ave. Sub	CBL-0016	In	0.00	0.0	0.0	0.0	0.0	0.00
STAR Campus Bus 1				0.0	0.0	0.0	0.0	
Sandy Brae Sub	CBL-0004	In	0.08	31,749.8	24,856.2	40,322.2	808.1	0.79
BUS-0010				22.9	32.4	39.7	165.5	
STAR Campus Bus 2	CBL-0019	In	0.24	-18,518.2	-13,848.0	23,123.4	437.0	0.80
BUS-0064				38.2	54.0	66.2	89.5	
STAR Campus Bus 2	CBL-0020	In	0.00	0.0	0.0	0.0	0.0	0.00
Wyoming Rd.				0.0	0.0	0.0	0.0	

2-Winding Transformers

From Bus To Bus	Component Name	In/Out Service	%VD	kW Loss	kvar Loss	kVA Loss	LF Amps Rating %	PF
138 kV Bus 34.5 kV Bus 3	T3	In	-0.19	46,253.8 128.0	35,212.2 4,170.2	58,131.8 4,172.1	257.0 61.5	0.80
138 kV Bus 34.5 kV Bus 4	T4	In	3.42	81,273.6 418.3	66,588.1 13,622.9	105,068.4 13,629.3	465.0 111.2	0.77
138 kV Bus 34.5 kV Bus 5	T5	In	-2.29	37,279.8 64.6	17,762.6 2,104.4	41,295.2 2,105.4	183.0 43.7	0.90
BUS-0060 STAR Campus Bus 1	XF2-0004	In	0.00	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.00
BUS-0060 STAR Campus Bus 2	XF2-0005	In	0.00	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.00

Pi Impedances

From Bus To Bus	Component Name	%VD	kW Loss	kvar Loss	kVA Loss	LF Amps Rating %	PF
STAR Campus Bu STAR Campus Bu	PI-0010	0.00	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.00
34.5 kV Bus 4 34.5 kV Bus 3	Tie Bus 3 to 4	0.00	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.00
34.5 kV Bus 5 34.5 kV Bus 4	Tie Bus 4 to 5	0.00	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.00
34.5 kV Bus 5 34.5 kV Bus 3	Tie Bus 5 to 3	0.00	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.00

Transmission Lines

From Bus To Bus	Component Name	%VD	kW Loss	kvar Loss	kVA Loss	LF Amps Rating %	PF
BUS-0007 BUS-0008	XLN-0001	7.46	47,691.3 1,976.1	31,864.8 5,727.3	57,357.0 6,058.6	1,054.6 0.0	0.83
BUS-0010 BUS-0062	XLN-0002	2.43	31,726.9 458.1	24,823.8 1,326.5	40,284.1 1,403.4	808.1 0.0	0.79
BUS-0012 BUS-0049	XLN-0003	0.82	27,716.2 65.3	19,348.0 416.7	33,801.3 421.8	597.6 0.0	0.82
BUS-0049 BUS-0014	XLN-0004	0.00	0.0 0.0	-1.2 -1.2	1.2 1.2	0.0 0.0	0.00
BUS-0016 BUS-0017	XLN-0005	2.42	27,597.7 353.3	18,823.8 1,019.5	33,406.1 1,079.0	597.6 0.0	0.83
BUS-0017 E. Chestnuthill Hill Rc	XLN-0006	0.87	24,853.0 116.9	17,589.6 337.0	30,447.8 356.7	559.2 0.0	0.82
BUS-0064 E. Chestnuthill Hill Rc	XLN-0007	1.46	-18,556.4 149.8	-13,902.1 430.1	23,186.4 455.4	437.0 0.0	0.80
BUS-0031 BUS-0055	XLN-0008	1.14	23,728.2 138.7	14,368.4 398.5	27,739.4 421.9	480.0 0.0	0.86
BUS-0033 University of Delaware	XLN-0009	0.17	13,464.8 18.8	1,258.5 52.2	13,523.5 55.5	234.0 0.0	1.00
34.5 kV Bus 4 BUS-0053	XLN-0010	2.10	14,365.9 164.4	9,273.7 467.1	17,099.2 495.2	314.2 0.0	0.84
BUS-0038 E. Main St.	XLN-0012	0.67	18,768.2 68.2	11,784.6 195.4	22,161.2 206.9	407.5 0.0	0.85
BUS-0050 Wyoming Rd.	XLN-0013	1.28	18,398.1 123.1	11,677.8 352.0	21,791.4 372.9	385.3 0.0	0.84

From Bus To Bus	Component Name	%VD	kW Loss	kvar Loss	kVA Loss	LF Amps Rating %	PF
BUS-0049	XLN-0014		27,650.8	18,932.4	33,511.3	597.6	0.83
BUS-0054		0.16	22.7	65.5	69.3	0.0	
BUS-0055	XLN-0015		6,172.4	3,003.7	6,864.4	120.2	0.90
Fremont Rd. Sub		0.22	7.4	17.9	19.3	0.0	
BUS-0055	XLN-0016		17,417.1	10,966.2	20,581.8	360.4	0.85
W. Main St.		0.85	77.1	219.8	232.9	0.0	

Appendix III

Project: Base Case with Max. STAR Campus Buildout
Scenario: Srvd from 2 new Kershaw Fdrs.

Load Flow Summary Report

Load Flow Study Settings

Include Source Impedance	Yes	Load Acceleration Factor	1.00
Solution Method	Exact (Iterative)	Bus Voltage Drop %	5.00
Load Specification	Connected Load	Branch Voltage Drop %	3.00
Generation Acceleration Factor	1.00		

Swing Generators

Source	In/Out Service	Vpu	Angle	kW	kvar	VD%	Utility Impedance		
Delmarva	In	1.00	0.00	165,944.4	105,193.4	4.96	0.01	+j	0.03
UTIL-0003	In	1.00	0.00	0.0	0.0	0.00	0.01	+j	0.03

Buses

Bus Name	In/Out Service	Design Volts	LF Volts	Angle Degree	PU Volts	%VD
138 kV Bus	In	138,000	131,154	-3.09	0.95	4.96
34.5 kV Bus 3	In	34,500	32,837	-37.06	0.95	4.82
34.5 kV Bus 4	In	34,500	33,190	-36.50	0.96	3.80
34.5 kV Bus 5	In	34,500	32,640	-37.62	0.95	5.39
BUS-0017	In	34,500	32,545	-37.61	0.94	5.67
BUS-0049	In	34,500	32,771	-37.22	0.95	5.01
BUS-0055	In	34,500	32,240	-38.29	0.93	6.55
BUS-0060	In	138,000	138,000	0.00	1.00	0.00
E. Chestnuthill Hill Rd.	In	34,500	32,489	-37.71	0.94	5.83
E. Main St.	In	34,500	32,974	-36.86	0.96	4.42
Fremont Rd. Sub	In	34,500	32,161	-38.43	0.93	6.78
Phillips Ave. Sub	In	34,500	32,550	-37.59	0.94	5.65
S. Chapel St.	In	34,500	32,533	-37.61	0.94	5.70
Sandy Brae Sub	In	34,500	32,627	-37.46	0.95	5.43
STAR Campus Bus 1	In	34,500	32,642	-37.21	0.95	5.38
STAR Campus Bus 2	In	34,500	32,458	-37.75	0.94	5.92
University of Delaware	In	34,500	32,504	-37.83	0.94	5.79
W. Main St.	In	34,500	31,965	-38.78	0.93	7.35

Bus Name	In/Out Service	Design Volts	LF Volts	Angle Degree	PU Volts	%VD
Wyoming Rd.	In	34,500	32,426	-37.77	0.94	6.01

Cables

From Bus To Bus	Component Name	In/Out Service	%VD	kW Loss	kvar Loss	kVA Loss	LF Amps Rating %	PF
34.5 kV Bus 3 BUS-0012	CBL-0005	In	0.01	8,231.1 0.5	4,077.5 0.7	9,185.7 0.8	161.5 16.5	0.90
34.5 kV Bus 3 BUS-0050	CBL-0014	In	0.03	19,476.5 5.0	9,726.0 7.1	21,769.9 8.6	382.8 78.4	0.89
34.5 kV Bus 3 STAR Campus Bus 1	CBL-0024	In	0.56	27,490.2 120.2	17,132.5 170.1	32,391.9 208.3	569.5 38.9	0.85
34.5 kV Bus 4 BUS-0007	CBL-0002	In	0.01	12,711.3 1.2	6,405.2 1.6	14,233.9 2.0	247.6 50.7	0.89
34.5 kV Bus 4 BUS-0038	CBL-0013	In	0.05	19,868.8 7.9	9,774.7 11.1	22,143.0 13.6	385.2 78.9	0.90
34.5 kV Bus 5 BUS-0031	CBL-0010	In	0.07	24,773.0 14.3	12,565.4 20.3	27,777.5 24.8	491.3 100.6	0.89
34.5 kV Bus 5 BUS-0033	CBL-0011	In	0.10	12,178.7 9.0	5,952.2 12.7	13,555.5 15.5	239.8 49.1	0.90
BUS-0008 Sandy Brae Sub	CBL-0003	In	0.01	12,601.2 1.2	6,099.4 1.7	13,999.7 2.1	247.7 50.7	0.90

From Bus To Bus	Component Name	In/Out Service	%VD	kW Loss	kvar Loss	kVA Loss	LF Amps Rating %	PF
BUS-0014	CBL-0006	In	0.00	0.0	0.0	0.0	0.0	0.00
University of Delaware				0.0	0.0	0.0	0.0	
BUS-0017	CBL-0008	In	0.00	2,160.9	1,046.4	2,400.9	42.6	0.90
BUS-0021				0.1	0.1	0.1	8.7	
BUS-0021	CBL-0009	In	0.03	2,160.8	1,046.3	2,400.8	42.6	0.90
S. Chapel St.				0.8	0.2	0.8	29.5	
BUS-0053	CBL-0015	In	0.05	15,035.8	7,287.6	16,708.8	296.2	0.90
Phillips Ave. Sub				5.8	8.2	10.1	60.7	
BUS-0054	CBL-0007	In	0.04	8,224.2	4,045.9	9,165.5	161.5	0.90
BUS-0016				2.2	3.1	3.9	33.1	
BUS-0062	CBL-0017	In	0.00	0.0	0.0	0.0	0.0	0.00
STAR Campus Bus 1				0.0	0.0	0.0	0.0	
Phillips Ave. Sub	CBL-0016	In	0.00	0.0	0.0	0.0	0.0	0.00
STAR Campus Bus 1				0.0	0.0	0.0	0.0	
Sandy Brae Sub	CBL-0004	In	0.00	0.0	-4.7	4.7	0.1	0.00
BUS-0010				0.0	0.0	0.0	0.0	
STAR Campus Bus 2	CBL-0025	In	0.53	-25,438.2	-15,760.8	29,925.0	532.3	0.85
34.5 kV Bus 5				105.0	148.6	181.9	36.3	

From Bus To Bus	Component Name	In/Out Service	%VD	kW Loss	kvar Loss	kVA Loss	LF Amps Rating %	PF
STAR Campus Bus 2 BUS-0064	CBL-0019	In	0.00	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.00
STAR Campus Bus 2 Wyoming Rd.	CBL-0020	In	0.00	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.00

2-Winding Transformers

From Bus To Bus	Component Name	In/Out Service	%VD	kW Loss	kvar Loss	kVA Loss	LF Amps Rating %	PF
138 kV Bus 34.5 kV Bus 3	T3	In	-0.14	55,362.0 164.1	36,281.2 5,345.3	66,191.2 5,347.8	291.0 69.6	0.84
138 kV Bus 34.5 kV Bus 4	T4	In	-1.16	47,876.3 114.4	27,606.4 3,726.3	55,265.3 3,728.0	243.0 58.2	0.87
138 kV Bus 34.5 kV Bus 5	T5	In	0.43	62,706.1 211.2	41,305.8 6,878.8	75,088.1 6,882.1	331.0 79.0	0.84
BUS-0060 STAR Campus Bus 1	XF2-0004	In	0.00	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.00
BUS-0060 STAR Campus Bus 2	XF2-0005	In	0.00	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.00

Pi Impedances

From Bus To Bus	Component Name	%VD	kW Loss	kvar Loss	kVA Loss	LF Amps Rating %	PF
STAR Campus Bu STAR Campus Bu	PI-0010	0.00	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.00
34.5 kV Bus 4 34.5 kV Bus 3	Tie Bus 3 to 4	0.00	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.00
34.5 kV Bus 5 34.5 kV Bus 4	Tie Bus 4 to 5	0.00	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.00
34.5 kV Bus 5 34.5 kV Bus 3	Tie Bus 5 to 3	0.00	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.00

Transmission Lines

From Bus To Bus	Component Name	%VD	kW Loss	kvar Loss	kVA Loss	LF Amps Rating %	PF
BUS-0007	XLN-0001	1.61	12,710.2	6,403.6	14,232.1	247.6	0.89
BUS-0008			109.0	304.2	323.1	0.0	
BUS-0010	XLN-0002	0.00	0.0	-4.7	4.7	0.1	0.00
BUS-0062			0.0	-4.7	4.7	0.0	
BUS-0012	XLN-0003	0.18	8,230.6	4,076.8	9,185.0	161.5	0.90
BUS-0049			4.8	27.8	28.2	0.0	
BUS-0049	XLN-0004	0.00	0.0	-1.2	1.2	0.0	0.00
BUS-0014			0.0	-1.2	1.2	0.0	
BUS-0016	XLN-0005	0.58	8,222.0	4,042.8	9,162.1	161.5	0.90
BUS-0017			25.8	68.3	73.0	0.0	
BUS-0017	XLN-0006	0.16	6,035.3	2,928.1	6,708.1	119.0	0.90
E. Chestnuthill Hill Rc			5.3	12.9	13.9	0.0	
BUS-0064	XLN-0007	0.00	0.0	0.0	0.0	0.0	0.00
E. Chestnuthill Hill Rc			0.0	-5.2	5.2	0.0	
BUS-0031	XLN-0008	1.09	24,758.6	12,545.1	27,755.5	491.3	0.89
BUS-0055			145.3	418.0	442.5	0.0	
BUS-0033	XLN-0009	0.30	12,169.8	5,939.6	13,541.8	239.8	0.90
University of Delaware			19.8	55.1	58.5	0.0	
34.5 kV Bus 4	XLN-0010	1.80	15,181.8	7,700.1	17,022.9	296.1	0.89
BUS-0053			146.0	412.5	437.6	0.0	
BUS-0038	XLN-0012	0.57	19,860.9	9,763.6	22,131.1	385.2	0.90
E. Main St.			60.9	174.0	184.4	0.0	
BUS-0050	XLN-0013	1.16	19,471.5	9,718.9	21,762.3	382.8	0.89
Wyoming Rd.			121.5	347.3	367.9	0.0	

From Bus To Bus	Component Name	%VD	kW Loss	kvar Loss	kVA Loss	LF Amps Rating %	PF
BUS-0049 BUS-0054	XLN-0014	0.04	8,225.8 1.7	4,050.3 4.4	9,168.9 4.7	161.5 0.0	0.90
BUS-0055 Fremont Rd. Sub	XLN-0015	0.23	6,172.7 7.7	3,004.9 19.0	6,865.2 20.5	122.9 0.0	0.90
BUS-0055 W. Main St.	XLN-0016	0.80	18,440.6 80.6	9,122.3 230.1	20,573.5 243.8	368.4 0.0	0.90

Appendix IV

Project: Served from STAR Campus Sub
Scenario: Srvd from STAR Campus Sub

Load Flow Summary Report

Load Flow Study Settings

Include Source Impedance	Yes	Load Acceleration Factor	1.00
Solution Method	Exact (Iterative)	Bus Voltage Drop %	5.00
Load Specification	Connected Load	Branch Voltage Drop %	3.00
Generation Acceleration Factor	1.00		

Swing Generators

Source	In/Out Service	Vpu	Angle	kW	kvar	VD%	Utility Impedance
Delmarva	In	1.00	0.00	78,180.4	41,530.7	1.95	0.01 +j 0.03
UTIL-0003	In	1.00	0.00	82,887.8	59,469.7	2.63	0.01 +j 0.03

Buses

Bus Name	In/Out Service	Design Volts	LF Volts	Angle Degree	PU Volts	%VD
138 kV Bus	In	138,000	135,312	-1.44	0.98	1.95
34.5 kV Bus 3	In	34,500	34,249	-32.13	0.99	0.73
34.5 kV Bus 4	In	34,500	34,225	-33.44	0.99	0.80
34.5 kV Bus 5	In	34,500	34,324	-33.90	0.99	0.51
BUS-0017	In	34,500	34,209	-32.30	0.99	0.84
BUS-0049	In	34,500	34,242	-32.18	0.99	0.75
BUS-0060	In	138,000	134,375	-1.48	0.97	2.63
E. Chestnuthill Hill Rd.	In	34,500	34,049	-34.09	0.99	1.31
E. Main St.	In	34,500	33,996	-33.74	0.99	1.46
Fremont Rd. Sub	In	34,500	34,250	-34.02	0.99	0.73
Phillips A	In	34,500	33,740	-34.69	0.98	2.20
Phillips B	In	34,500	33,937	-33.83	0.98	1.63
S. Chapel St.	In	34,500	34,197	-32.30	0.99	0.88
Sandy Brae Sub A	In	34,500	33,615	-34.90	0.97	2.57
Sandy Brae Sub B	In	34,500	33,995	-33.83	0.99	1.46
STAR Campus Bus 1	In	34,500	33,752	-34.68	0.98	2.17
STAR Campus Bus 2	In	34,500	34,181	-33.89	0.99	0.93
University of Delaware	In	34,500	34,244	-34.15	0.99	0.74

Bus Name	In/Out Service	Design Volts	LF Volts	Angle Degree	PU Volts	%VD
W. Main St.	In	34,500	33,728	-34.69	0.98	2.24
Wyoming Sub A	In	34,500	34,144	-33.92	0.99	1.03
Wyoming Sub B	In	34,500	34,084	-32.40	0.99	1.21

Cables

From Bus To Bus	Component Name	In/Out Service	%VD	kW Loss	kvar Loss	kVA Loss	LF Amps Rating %	PF
34.5 kV Bus 3 BUS-0012	CBL-0005	In	0.00	2,393.4 0.0	209.6 0.0	2,402.5 0.1	40.5 4.1	1.00
34.5 kV Bus 3 BUS-0050	CBL-0014	In	0.01	8,210.5 0.8	4,018.8 1.1	9,141.3 1.4	154.1 31.6	0.90
34.5 kV Bus 4 BUS-0007	CBL-0002	In	0.00	5,418.8 0.2	2,656.3 0.3	6,034.9 0.3	101.8 20.9	0.90
34.5 kV Bus 4 BUS-0038	CBL-0013	In	0.05	18,764.7 7.4	11,763.0 10.5	22,146.9 12.8	373.6 76.5	0.85
34.5 kV Bus 5 BUS-0031	CBL-0010	In	0.06	17,493.0 7.2	11,171.0 10.2	20,755.6 12.5	349.1 71.5	0.84
34.5 kV Bus 5 BUS-0033	CBL-0011	In	0.07	13,471.9 8.1	1,266.8 11.4	13,531.3 14.0	227.6 46.6	1.00
34.5 kV Bus 5 BUS-0068	CBL-0021	In	0.00	6,171.9 0.1	3,002.0 0.2	6,863.3 0.3	115.4 23.6	0.90
BUS-0008 Sandy Brae Sub B	CBL-0003	In	0.00	5,400.2 0.2	2,615.6 0.3	6,000.3 0.3	101.9 20.9	0.90

From Bus To Bus	Component Name	In/Out Service	%VD	kW Loss	kvar Loss	kVA Loss	LF Amps Rating %	PF
BUS-0014	CBL-0006	In	0.00	0.0	0.0	0.0	0.0	0.00
University of Delaware				0.0	0.0	0.0	0.0	
BUS-0017	CBL-0008	In	0.00	2,391.2	214.7	2,400.8	40.5	1.00
BUS-0021				0.1	0.1	0.1	8.3	
BUS-0021	CBL-0009	In	0.03	2,391.1	214.6	2,400.7	40.5	1.00
S. Chapel St.				0.7	0.2	0.7	28.1	
BUS-0053	CBL-0015	In	0.02	6,121.0	3,794.2	7,201.6	122.5	0.85
Phillips B				1.0	1.4	1.7	25.1	
BUS-0054	CBL-0007	In	0.01	2,392.9	212.2	2,402.3	40.5	1.00
BUS-0016				0.1	0.2	0.2	8.3	
BUS-0062	CBL-0017	In	0.04	-7,213.9	-3,521.5	8,027.5	137.4	0.90
STAR Campus Bus 1				2.0	2.8	3.4	28.1	
Phillips A	CBL-0016	In	0.03	-8,550.0	-4,141.0	9,500.0	162.6	0.90
STAR Campus Bus 1				2.2	3.1	3.9	33.3	
Sandy Brae Sub A	CBL-0004	In	0.01	-7,200.0	-3,487.1	8,000.0	137.4	0.90
BUS-0010				0.7	0.9	1.1	28.1	
STAR Campus Bus 2	CBL-0019	In	0.06	6,042.7	2,947.7	6,723.3	113.6	0.90
BUS-0064				2.6	3.6	4.5	23.3	

From Bus To Bus	Component Name	In/Out Service	%VD	kW Loss	kvar Loss	kVA Loss	LF Amps Rating %	PF
STAR Campus Bus 2	CBL-0020	In	0.11	11,168.8	5,417.5	12,413.3	209.7	0.90
Wyoming Sub A				8.8	12.4	15.2	42.9	

2-Winding Transformers

From Bus To Bus	Component Name	In/Out Service	%VD	kW Loss	kvar Loss	kVA Loss	LF Amps Rating %	PF
138 kV Bus	T3	In	-1.22	10,608.5	4,379.4	11,476.9	49.0	0.92
34.5 kV Bus 3				4.6	151.0	151.0	11.7	
138 kV Bus	T4	In	-1.15	30,375.7	19,779.8	36,248.1	155.0	0.84
34.5 kV Bus 4				46.2	1,506.0	1,506.7	37.0	
138 kV Bus	T5	In	-1.44	37,196.1	17,371.6	41,052.7	175.0	0.91
34.5 kV Bus 5				59.3	1,931.7	1,932.6	41.9	
BUS-0060	XF2-0004	In	-0.46	47,091.2	35,075.6	58,718.6	252.0	0.80
STAR Campus Bus 1				123.0	4,007.2	4,009.1	60.3	
BUS-0060	XF2-0005	In	-1.70	35,796.7	24,394.1	43,318.3	186.0	0.83
STAR Campus Bus 2				67.0	2,180.9	2,181.9	44.5	

Pi Impedances

From Bus To Bus	Component Name	%VD	kW Loss	kvar Loss	kVA Loss	LF Amps Rating %	PF
STAR Campus Bu STAR Campus Bu	PI-0010	0.00	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.00
Phillips B Phillips A	PI-0011	0.00	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.00
Wyoming Sub B	PI-0012	0.00	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.00
Sandy Brae Sub B Sandy Brae Sub A	PI-0013	0.00	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.00
34.5 kV Bus 4 34.5 kV Bus 3	Tie Bus 3 to 4	0.00	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.00
34.5 kV Bus 5 34.5 kV Bus 4	Tie Bus 4 to 5	0.00	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.00
34.5 kV Bus 5 34.5 kV Bus 3	Tie Bus 5 to 3	0.00	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.00

Transmission Lines

From Bus To Bus	Component Name	%VD	kW Loss	kvar Loss	kVA Loss	LF Amps Rating %	PF
BUS-0007 BUS-0008	XLN-0001	0.66	5,418.6 18.4	2,656.0 40.4	6,034.6 44.4	101.8 0.0	0.90
BUS-0010 BUS-0062	XLN-0002	0.35	-7,200.7 13.2	-3,488.1 33.4	8,001.0 35.9	137.4 0.0	0.90
BUS-0012 BUS-0049	XLN-0003	0.02	2,393.3 0.3	209.5 -1.2	2,402.5 1.3	40.5 0.0	1.00
BUS-0049 BUS-0014	XLN-0004	0.00	0.0 0.0	-1.3 -1.3	1.3 1.3	0.0 0.0	0.00
BUS-0016 BUS-0017	XLN-0005	0.08	2,392.8 1.6	212.0 -2.6	2,402.2 3.1	40.5 0.0	1.00
BUS-0017 E. Chestnuthill Hill Rc	XLN-0006	0.00	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.00
BUS-0064 E. Chestnuthill Hill Rc	XLN-0007	0.32	6,040.1 10.1	2,944.1 23.6	6,719.4 25.7	113.6 0.0	0.90
BUS-0031 BUS-0067	XLN-0008	0.84	17,485.8 73.4	11,160.8 208.6	20,744.0 221.1	349.1 0.0	0.84
BUS-0033 University of Delaware	XLN-0009	0.16	13,463.8 17.8	1,255.4 49.1	13,522.2 52.3	227.6 0.0	1.00
34.5 kV Bus 4 BUS-0053	XLN-0010	0.81	6,145.9 25.0	3,854.4 60.2	7,254.6 65.2	122.4 0.0	0.85
BUS-0038 E. Main St.	XLN-0012	0.61	18,757.3 57.3	11,752.6 163.4	22,135.0 173.1	373.6 0.0	0.85
BUS-0050 Wyoming Sub B	XLN-0013	0.46	8,209.7 19.7	4,017.7 51.1	9,140.1 54.7	154.1 0.0	0.90

From Bus To Bus	Component Name	%VD	kW Loss	kvar Loss	kVA Loss	LF Amps Rating %	PF
BUS-0049	XLN-0014		2,393.0	212.1	2,402.4	40.5	1.00
BUS-0054		0.01	0.1	-0.2	0.2	0.0	
BUS-0068	XLN-0015		6,171.8	3,001.8	6,863.1	115.4	0.90
Fremont Rd. Sub		0.21	6.8	15.9	17.3	0.0	
BUS-0067	XLN-0016		17,412.4	10,952.2	20,570.4	349.2	0.85
W. Main St.		0.83	72.4	205.8	218.2	0.0	

Appendix V

Appendix VI

					DATE PREPARED		8/18/2014		SHEET 1 of 1			
ACTIVITY AND LOCATION University of Delaware STAR Campus Newark, DE			CONSTRUCTION CONTRACT NO.				IDENTIFICATION NUMBER					
			ESTIMATED BY QUAD THREE GROUP, INC.				CATEGORY CODE NUMBER					
			STATUS OF DESIGN 30% 100% FINAL OTHER Budget				JOB ORDER NUMBER					
PROJECT TITLE New 138kV x 34.5kV Substation			ENGINEERING ESTIMATE									
ITEM DESCRIPTION			QUANTITY		UNIT COST		TOTAL		UNIT COST		TOTAL	
			NUMBER	UNIT								
Double circuit steel pole 138kV line (DPL est. cost)			500	lf	\$150	\$75,000	\$320	\$160,000	\$470	\$235,000		
138kV circuit breakers			2	ea	\$72,000	\$144,000	\$5,000	\$10,000	\$77,000	\$154,000		
138kV structure and equipment (switches, inslators,			1	ls	\$210,000	\$210,000	\$45,000	\$45,000	\$255,000	\$255,000		
138kV - 34.5kV, 60/100MVA transformer			2	ea	\$2,030,000	\$4,060,000	\$16,000	\$32,000	\$2,046,000	\$4,092,000		
34kV circuit breakers (7 feeders, 2 banks, 1 tie)			10	ea	\$43,000	\$430,000	\$4,000	\$40,000	\$47,000	\$470,000		
34kV structure and equipment (switches, insulators,			1	ls	\$380,000	\$380,000	\$105,000	\$105,000	\$485,000	\$485,000		
Relay Panels			1	ls	\$310,000	\$310,000	\$30,000	\$30,000	\$340,000	\$340,000		
Control house and control wiring			1	ls			\$140,000	\$140,000	\$140,000	\$140,000		
34kV UG feeders (substation site only) and gang			1	ls	\$156,000	\$156,000	\$78,000	\$78,000	\$234,000	\$234,000		
34kV aerial feeders and extensions			1	ls	\$60,000	\$60,000	\$180,000	\$180,000	\$240,000	\$240,000		
Commissioning and Testing			1	ls			\$50,000	\$50,000	\$50,000	\$50,000		
Site preparation			2	ac			\$50,000	\$100,000	\$50,000	\$100,000		
Foundations (including transformer containment)			1	ls			\$280,000	\$280,000	\$280,000	\$280,000		
Ground grid			1	ls			\$48,000	\$48,000	\$48,000	\$48,000		
Screen Wall - 8' high decorative block with gates			1000	lf			\$300	\$300,000	\$300	\$300,000		
General Conditions, Bonds and Insurance			1	ls			\$60,000	\$60,000	\$60,000	\$60,000		
Subtotal						\$5,825,000		\$1,658,000		\$7,483,000		
Overhead & Profit (contractor labor and materials			20	%				\$331,600		\$331,600		
Total Cost of Construction										\$7,814,600		
Contingency										\$300,000		
Engineering										\$300,000		
Escalation (2.5% per year - 2 years)										\$426,000		
Total Cost of Project										\$8,840,600		
NOTES:												
1. Estimate includes an estimated DPL line construction cost but no other DPL interconnect fees.												
2. Estimate includes new 138kV facilities per Delmarva Power												
3. Material costs are only for thosemajor items that may be bid by the City and furnished to the contractor for												
4. 34kV duct system beyond substation fence by												