LOUISIANA STATE UNIVERSITY

COMPREHENSIVE & STRATEGIC CAMPUS MASTER PLAN

APPENDIX N - Campus Utilities Assessment Findings

Louisiana State University
Campus Master Plan – Campus Utilities

Introduction

Based on the new campus growth plans identified by the Master Plan, overall campus gross load projections were estimated for the central heating, cooling and electrical systems as summarized in the following Figure LP-1.

NEW BUILDING PROGRAM SPACE		HEATING		COOLING		POWER (11)		
School / Type	GSF	Load Factor BTUH/GSF	Steam Load Lbs/Hr	Load Factor GSF/Ton	Cooling Load Tons	Load Factor VA/GSF	Power Load kVA	
Agriculture	88,000	30	2,640	350	251	6.0	528	
Art and Design	70,000	35	2,450	300	233	6.4	451	
Athletics per LSU (1)	295,000	35	-	350	-	6.0	1,768	
Business	36,000	30	1,080	400	90	5.4	193	
Engineering	297,000	50	14,850	250	1,188	7.8	2,310	
Housing per LSU (1)(2)	360,000	35	-	325	-	7.1	2,542	
Human Sciences and Education	67,000	30	2,010	350	191	6.0	402	
Humanities and Social Sciences	77,000	30	2,310	350	220	6.0	462	
Law	57,000	30	1,710	350	163	5.7	325	
LETC per LSU	113,000	35	3,955	300	377	6.4	729	
Library	375,000	30	11,250	300	1,250	5.6	2,118	
Mass Communications	48,000	30	1,440	350	137	6.0	288	
Music and Art	13,000	30	390	325	40	5.9	77	
Nicholson Mixed Use Dev. per LSU (1)(3)	260,000	35	-	325	-	7.1	1,836	
Science	177,000	70	12,390	200	885	8.7	1,544	
Coast and Environment	-	35	-	250	-	0.0	-	
Vet Med (1)	87,000	70	-	225	-	9.9	864	
New Peak Subtotals	2,420,000		56,475		5,026		16,435	
Load Diversity Factor			0.70		0.75		0.60	
New Total Diversified Loads			39,500		3,800		9,900	
Current Peak Loads per LSU Reports			100,000		22,800		41,200	(6)
Projected Diversified Peak Loads			**139,500**		**26,600**		**51,100**	
Existing Installed Capacity			500,000	(4)	25,600	(5)	102,000	(9)
Largest Piece of Equipment			150,000	(7)	6,200	(8)	40,000	(10)
Existing Firm Capacity			350,000		19,400		62,000	
Projected Net Capacity - Excess / (Shortage)			210,500		(7,200)		10,900	
Required Installed Capacity with N+1 Allowance			289,500		32,800		91,100	

Notes:
(1) Assume this space will be heated and cooled via local unitary equipment or other local utility plant
(2) LSU estimates 900,0000 GSF by 2040. Prorated for next 10 year plan = 360,000 GSF
(3) Net growth including demolition of existing and new development
(4) Operational Boilers (#4, #7 and #8) at Central Plant (350,000 lbs/hr). #6 emergency standby only (150,000 lbs/hr).
(5) Central Plant (21,900) and Highland Plant (3,700)
(6) Based on 35MW peak load at estimated 0.85 power factor
(7) Boiler #8, GE Turbine HRSG
(8) Chiller #6, combustion turbine driven
(9) Based on max fan rating of two (2) 24/32/40 MVA Substations and 18.7MW/22MVA Cogen
(10) One (1) 24/32/40 Substation at max fan rating
(11) Power Load for spaces served from central heating/cooling include power load at central utility plant

Figure LP-1: Campus Gross Load Projections

After applying a load diversity factor to the estimated additional connected loads, the new facilities are expected to add 39,500 lbs/hr of steam, 3,800 tons of cooling, and 9,900 kVA of power to the campus' current peak loads. When determining how much capacity should be installed in a campus central plant, it is standard practice to include provisions for the ability to meet the peak campus demand without the largest piece of equipment available in the event it failed or was unable to be operated for a variety of reasons. This is commonly referred to as having N+1 redundancy, and the remaining capacity after subtracting the capacity of the largest piece of equipment from the installed Capacity is also known as the plants firm capacity.

Considering the loads associated with the Master Plan, the existing heating and power equipment and systems appear to have adequate capacity to meet the new projected loads. Note that this would exclude a loss of natural gas, and/or purchased power services.

However, the chilled water system is already short of meeting the current peak load by 3,400 tons, and the projected peak load by 7,200 tons. To provide the recommended N+1 level of redundancy, the central chilled water system capacity should be increased by 3,400 tons as quickly as possible. A balance need of 3,800-tons should be added over time, as required to meet new loads as they are added to the system. It should be noted that chiller #6 is at the end of its useful life, and if its capacity were to be replaced with machines more similar in size to chillers #8, #9 and #10, the need to add new capacity could be deferred due to the smaller increment size.

Existing Systems

The existing LSU Central Plant is located near the southeast corner of the football stadium and is the primary source of heating and cooling for most of the academic buildings and some of the athletics, residential life and auxiliary services buildings on campus. A number of the remote athletics, residential life and auxiliary services facilities have their own unitary heating and cooling equipment that is owned and operated by the respective operating unit. There is a regional chilled water plant (Highland Utility Plant) that is interconnected to the Central Plant and serves most of the southern and eastern portions of campus. There is also a stand-alone heating and cooling plant that serves the LSU School of Veterinary Medicine. Electrical power that is generated at the Central Plant and parallel utility power from the local utility is supplied to essentially all campus buildings (academic, athletics, residential life, and auxiliary services) through LSU's campus distribution system.

The primary central campus utility production and distribution systems reviewed as part of this master planning effort that are in the Central Plant and Highland Plant are summarized herein. The flow diagram shown below in Figure CP-1 (prepared by Robert Buckley, Jr., 2006) illustrates the basic overall configuration of the Central Plant primary thermal and power equipment.

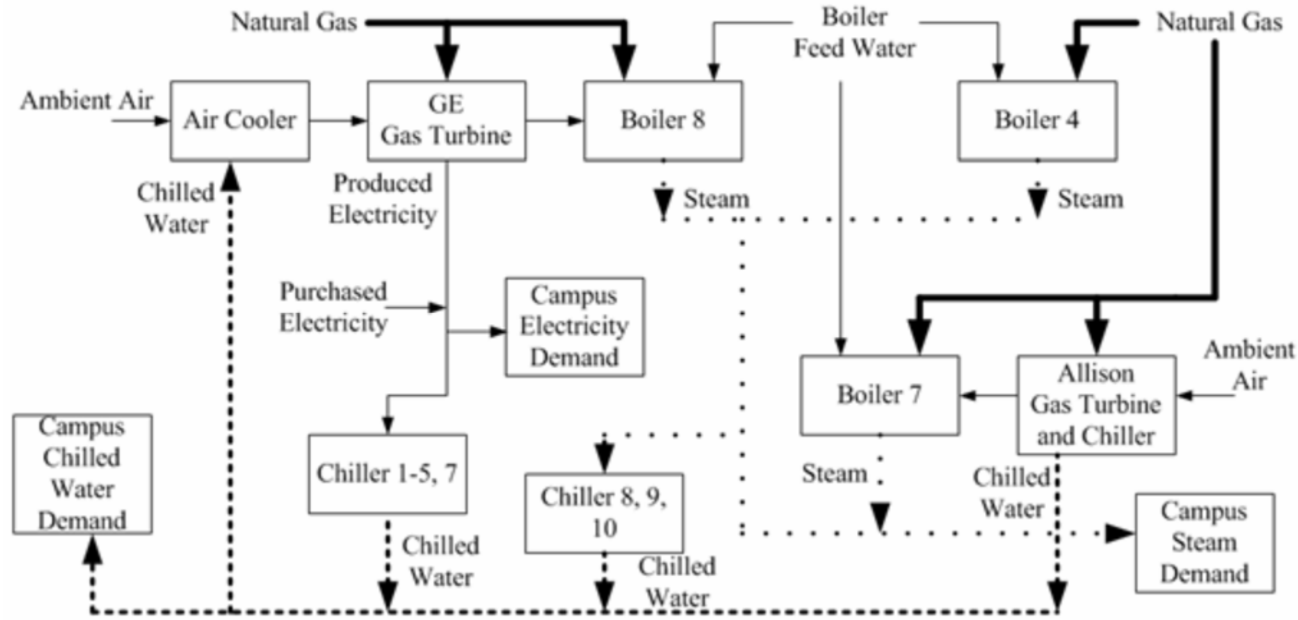

Figure CP-1: Central Plant Overall System Flow Diagram

<u>Heating System</u>
Heating capacity is currently supplied to the majority of the existing facilities from the Central Plant, which is equipped with two natural gas fired boilers and two combustion turbines with heat recovery steam generators (HRSG), or recovery boilers. The plant's natural gas boilers do not have fuel oil back-up. Steam is produced at 160 psig and distributed across campus at 90 psig.

The following summarizes the primary heating equipment that is installed in the central plant.

Boilers:
#1, #2, #3 and #5 - retired
#4 - 1991 – 100,000 lbs/hr
#6 - 1968 – 150,000 lbs/hr – not operational since 2000.
#7 - 1992 – 100,000 lbs/hr – Allison Turbine HRSG
#8 - 2004 – 150,000 lbs/hr – GE Turbine HRSG

Cogen Units:
1992 - 3.7 MW (Allison) combustion turbine with HRSG (boiler #7) has total output of 100,000 lbs/hr. The drive shaft for this turbine is also coupled with a 6,200-ton centrifugal chiller (#6) to allow for direct chiller water production by the gas turbine. There is also a piping project in process that will interconnect the output from boiler #7 to serve the steam turbine driven chillers #8, #9 and #10 (which are normally driven by the output of the 20 MW turbine and boiler #8).

2004 – 20 MW (GE) combustion turbine with HRSG (boiler #8) has total output of 150,000 lbs/hr.

Neither of the HRSG boilers (#7 and #8) can be directly fresh air fired so they cannot produce steam if the associated combustion turbines are not operational. This results in a relatively high level of risk considering the age of the other boilers in the system.

The Central Plant's steam condensing cooling towers for its combustion turbines have not been operational in several years.
It was reported by LSU staff that the CHP units and/or the lone operational boiler #4 can meet

current peak campus heating load of approximately 100,000 lbs/hr (not including plant auxiliaries and steam driven chillers). LSU staff have also suggested that the heating system should have enough capacity to serve approximately 500,000 GSF of new research space or 1,500,000 GSF of less energy intensive academic space.

The availability of all equipment and fuel sources is a concern. And, there is no back-up if the CHP units were unable to operate and boiler #4 failed. This is a real possibility because the high pressure natural gas service that serves the combustion turbine units is interruptible and experiences interruptions, such as a 3-month period in 2015.

The Central Plant heating control instrumentation is aged and has been experiencing more regular failures in recent years making reliable and efficient plant operations a challenge. A screen shot of the Central Plant controls graphics is below in Figure HT-1.

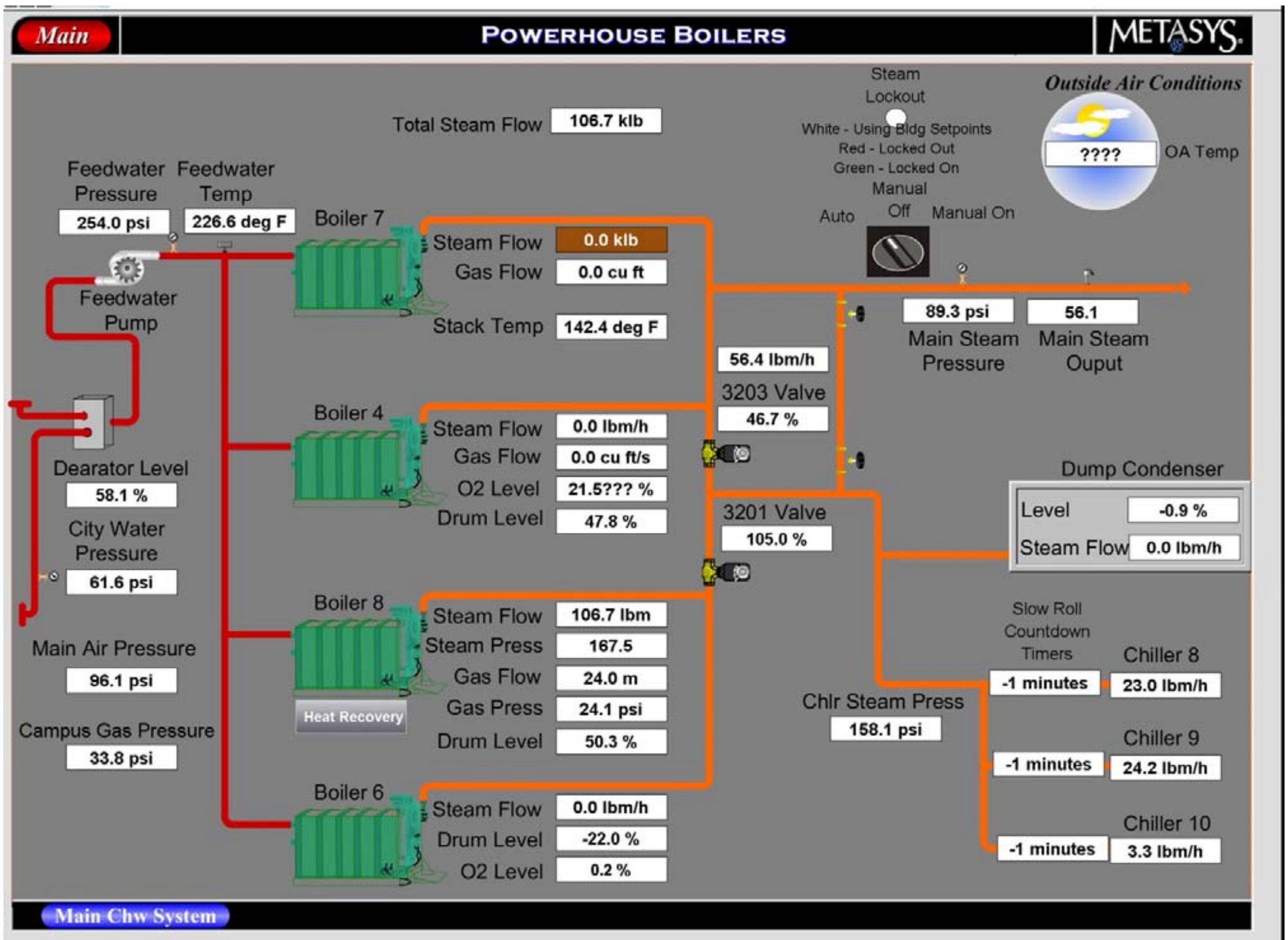

Figure HT-1: Central Plant Boilers Controls Graphics

At peak output, approximately 100,000 lbs/hr is distributed to heat the campus through a combination of tunnels and direct buried piping. Refer to the campus steam distribution map below in Figure HT-2 for routing of the existing steam tunnels and underground piping which totals over 4 miles.

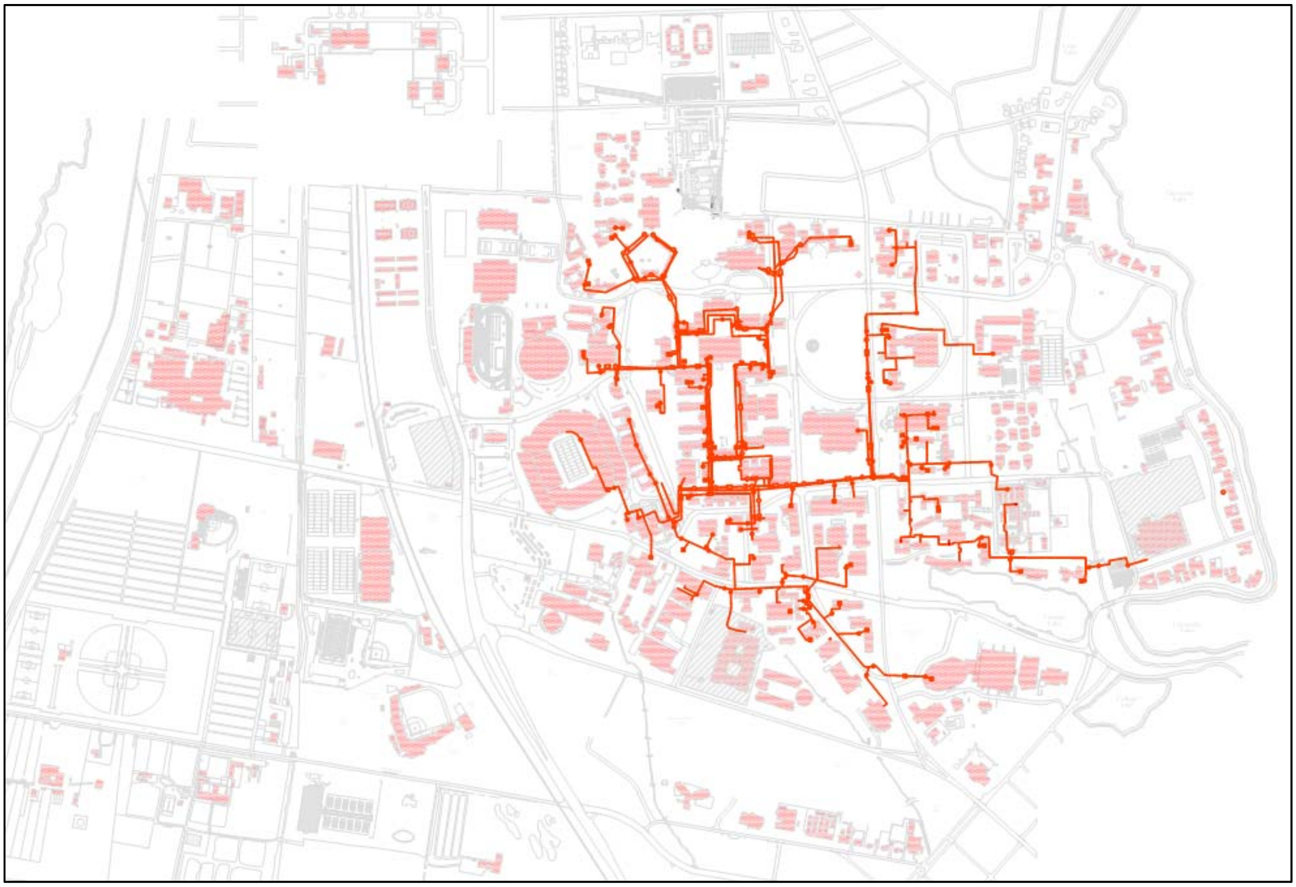

Figure HT-2: Existing Steam Distribution System Map

The poor condition of the lines on campus result in steam condensate return rates that vary between 20-50% with an average of 40%. The steam lines are also of varying quality, but most of the system leaks are believed to be in the condensate piping. A 2015 thermographic aerial survey indicates where the poor sections of pipes are located as it identifies where there are more significant losses in the system into the ground. LSU has been using this survey information to plan for the repair/replacement deficient sections of the steam distribution systems as practical, and expanding them where needed to serve new loads. In an effort to generally characterize the condition of piping sections LSU created the below color-coded map, Figure HT-3 in support of this Master Planning effort. Note that lines in poor condition could be rated as such for a variety of reasons such as age, condition, materials of construction, or size.

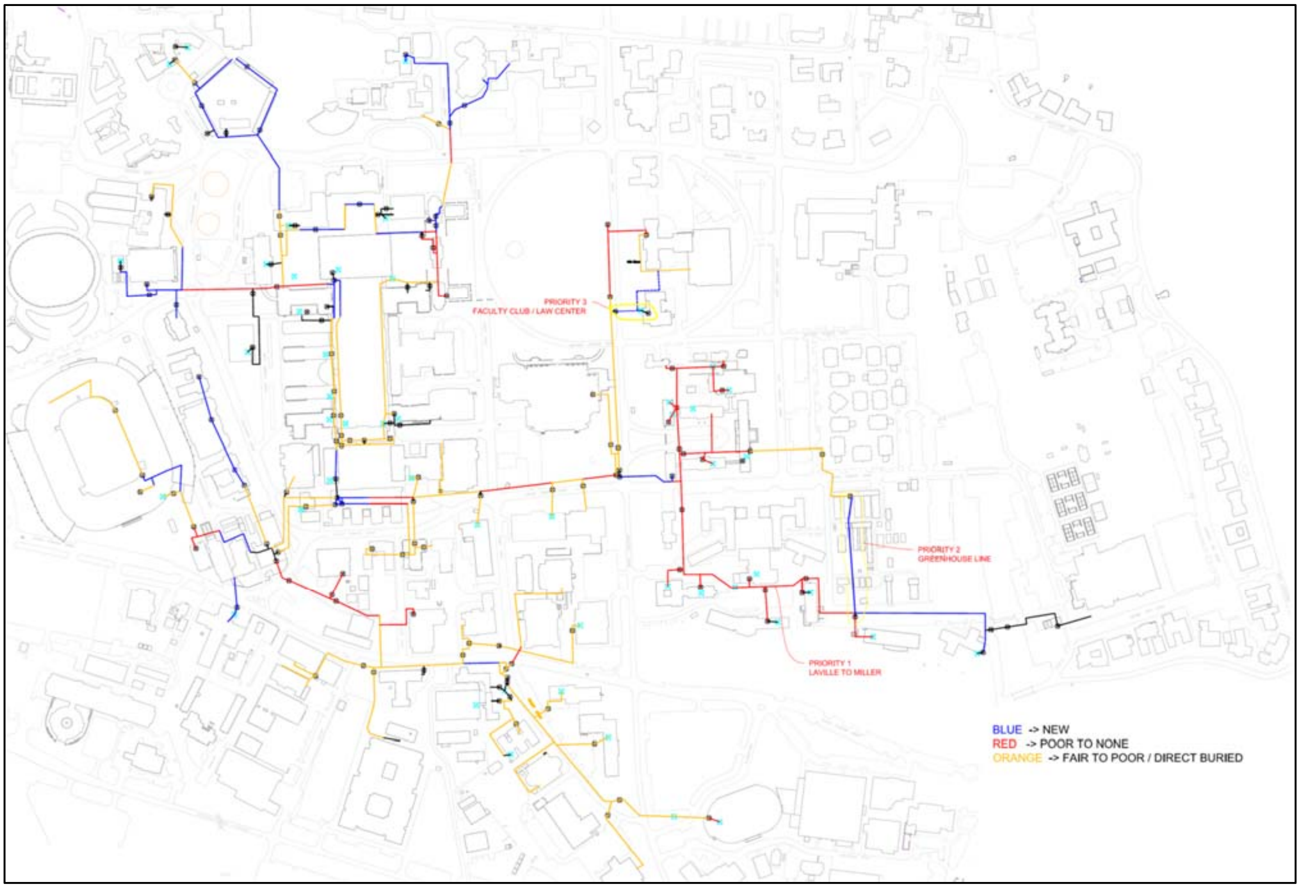

Figure HT-3: Steam Distribution Piping Conditions Map

Another concern with thermal distribution systems at LSU is the number of long radial mains versus looped mains. In a radial system, if a pipe fails, all the connected building downstream of the failure point would be impacted by the resulting outage. In a looped system, the piping is interconnected such that most or all of the buildings can be served from at least two different directions. This minimizes the outages associated with a single piping failure. The radial and looped sections of mains are color coded with blue and green respectively below in Figure HT-4. As the campus steam distribution system is expanded, the radial lines should be interconnected to create as many loops as practical.

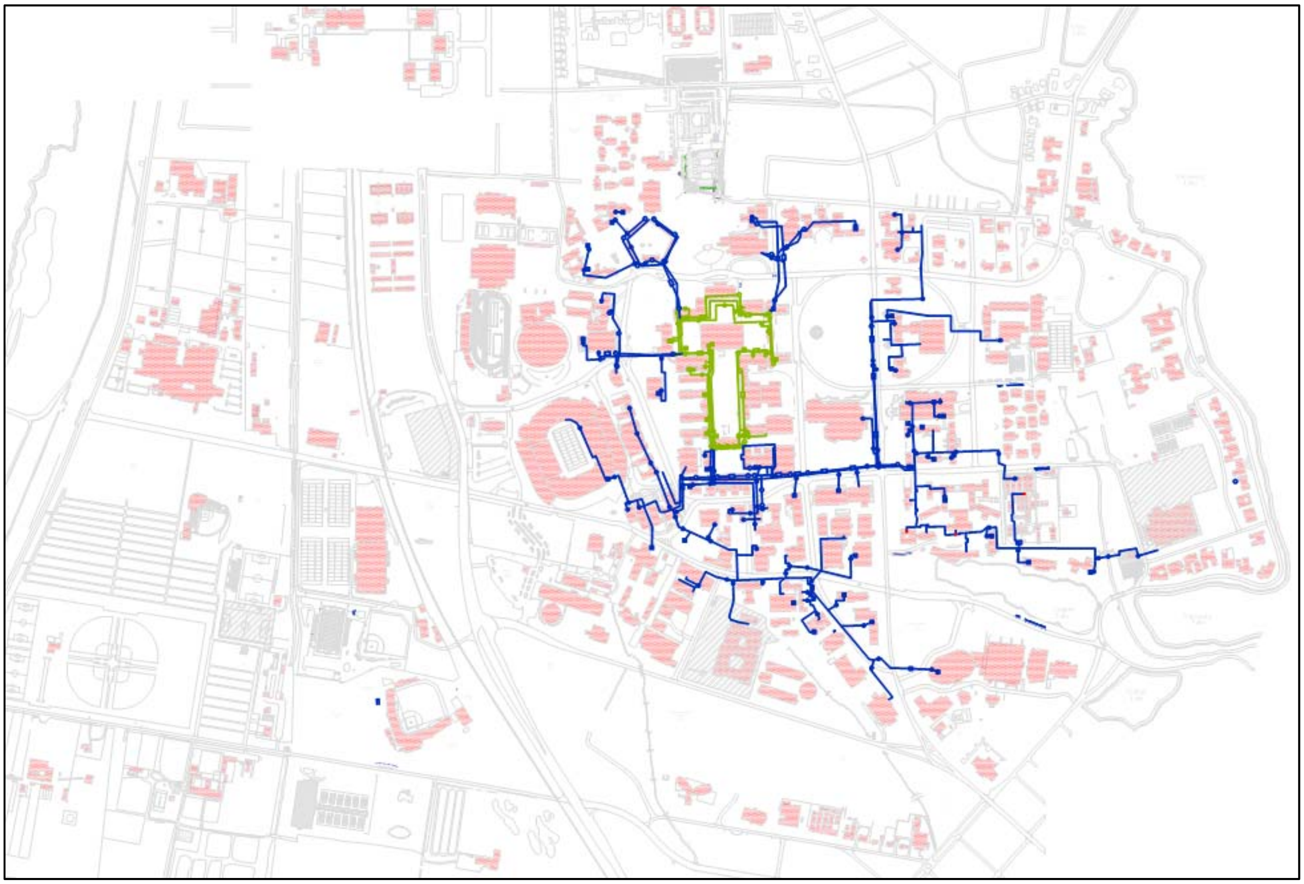

Figure HT-4: Steam Distribution Radial versus Looped Piping Map

LSU currently does not have or maintain a hydraulic model for the steam distribution network. This can be an invaluable tool when managing and maintaining a system as large as this one..

Steam is not metered at each building, but use is charged for non-academic buildings based on gross square footage and seasonal pro-rated hours of use. The academic buildings on campus are not metered and are not billed for their steam consumption. LSU staff would prefer to see all buildings equipped with utility meters as it promotes transparency and sustainability as well as enables far better system planning and management.

Natural gas service from the local utility (Pontchartrain Natural Gas – high pressure service for CHP and balance of service from Entergy) is delivered at 450 psig to the Central Plant CHP units and to a master meter located near the Central Plant. It is distributed across campus for a variety of building uses. LSU is not charged a variable-peak rate for any utility. The campus gas turbine works as the demand limiting device. LSU has a contract with Entergy for standby service during campus maintenance of Central Plant equipment.

LSU currently does not have or maintain a hydraulic model for the natural gas distribution network. It isn't known if the LSU owned portion of the system has sufficient capacity to support future growth. Refer to the below campus natural gas distribution map in Figure NG-1 for routing of the existing underground piping.

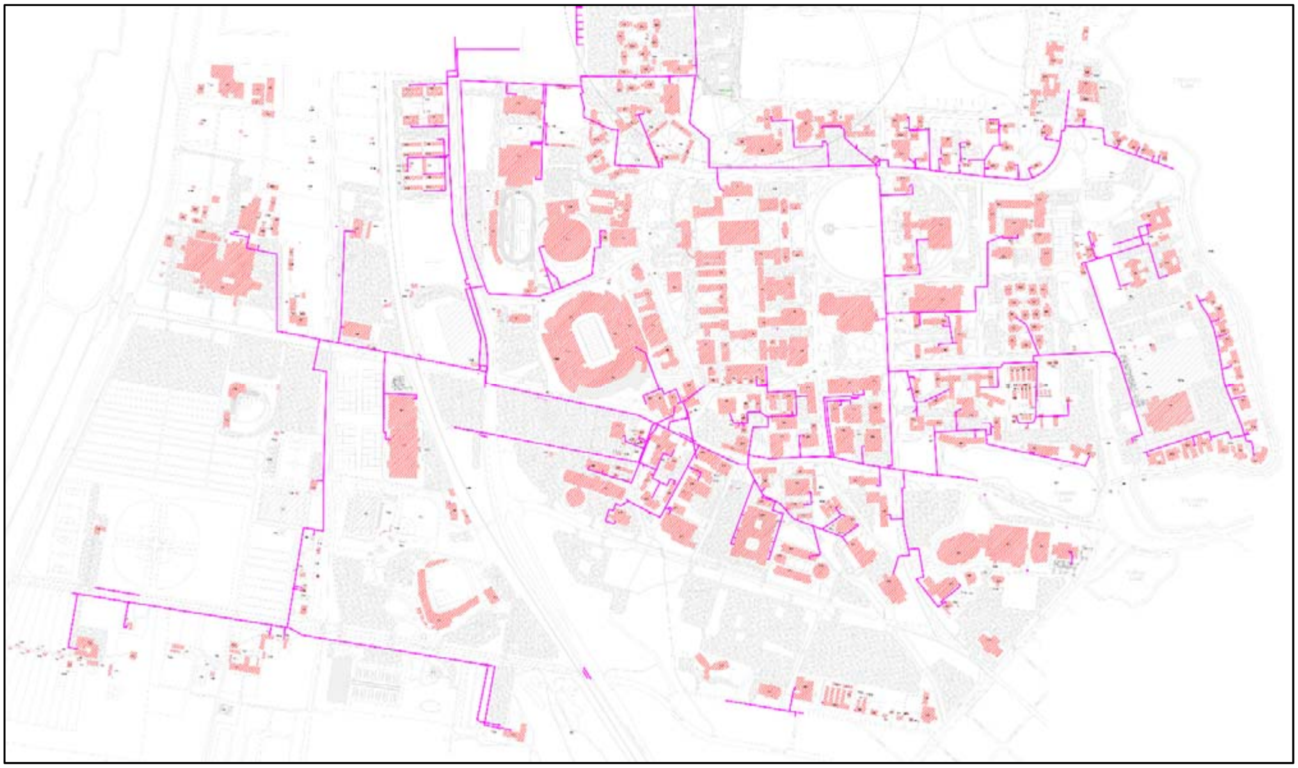

Figure NG-1: Existing Natural Gas Distribution System Map

Cooling System

Cooling capacity is currently supplied to the majority of the existing facilities from the Central Plant. In recent years, there is a trend for new, non-academic facilities to be constructed with their own chillers. The following summarizes the primary cooling equipment that is installed in the Central Plant.

Gas Turbine Driven Chiller
#6 – 1992 – 6,200 tons, York/JCI, R-22
This machine is in good operating condition and has been relatively reliable. There have been a few issues related to turbine operation since it was installed.

Steam Turbine Driven Chillers
#8 – 2004 – 2,100 tons, York/JCI, R-134a
#9 – 2004 – 2,100 tons, York/JCI, R-134a
#10 – 2004 – 2,100 tons, York/JCI, R-134a
These machines are associated with the CHP operations, are in good operating condition and are relatively reliable.

Electric Driven Chillers
#1 – 1995 – 1,600 tons, York/JCI, R-22
#2 – 1994 – 2,000 tons, York/JCI, R-22
#3 – 1991 – 1,000 tons, York/JCI, R-11
#4 – 2000 – 1,700 tons, York/JCI, R-134a
#5 – 1996 – 2,000 tons, York/JCI, R-22
#7 – 1991 – 1,100 tons, Trane, R-11

These machines are in varying states of condition and operation. None of these chillers have variable speed drives, which can be used to reduce energy consumption.

The chillers described above are currently served by three separate groups of cooling towers. The combustion turbine driven chiller is connected to a two cell, field erected tower by Ceramic Cooling Tower. The steam turbine driven chillers are connected to a four cell, field erected tower by Hamon. The electric driven chillers are connected to a bank of twelve metal packaged cooling towers. The latter were noted to be in very poor condition and in need of replacement. The following summarizes the capacities of these cooling towers:

Ceramic Cooling Tower Unilite – serves combustion turbine driven chiller #6
#6 - 2 cells – 1991 - 27,900 gpm

Hamon Cooling Tower – serves steam turbine driven chillers #8, #9 and #10
#8 - 4 cells – 2003 - 20,000 gpm

Packaged Cooling Towers – serves chillers #1, #2, #3, #4, #5 and #7 (assumed total flow 28,200 gpm)
#1, #3, #5 - 5 cells – 1991 – Marley
#2 - 3 Cells – 1994 – BAC
#7 - 2 Cells – 1995 – Marley
#4 - 2 Cells – 2000 – Marley

None of the existing cooling towers are equipped with variable frequency drives, which can be used to reduce energy consumption. To increase system reliability and operational flexibility, LSU would like to interconnect/manifold the various hydraulically isolated groups of cooling towers at the Central Plant.

The Central Plant cooling control instrumentation is aged and has been experiencing more regular failures in recent years making reliable and efficient plant operations a challenge. A screen shot of the Central Plant controls graphics is below in Figure CL-1.

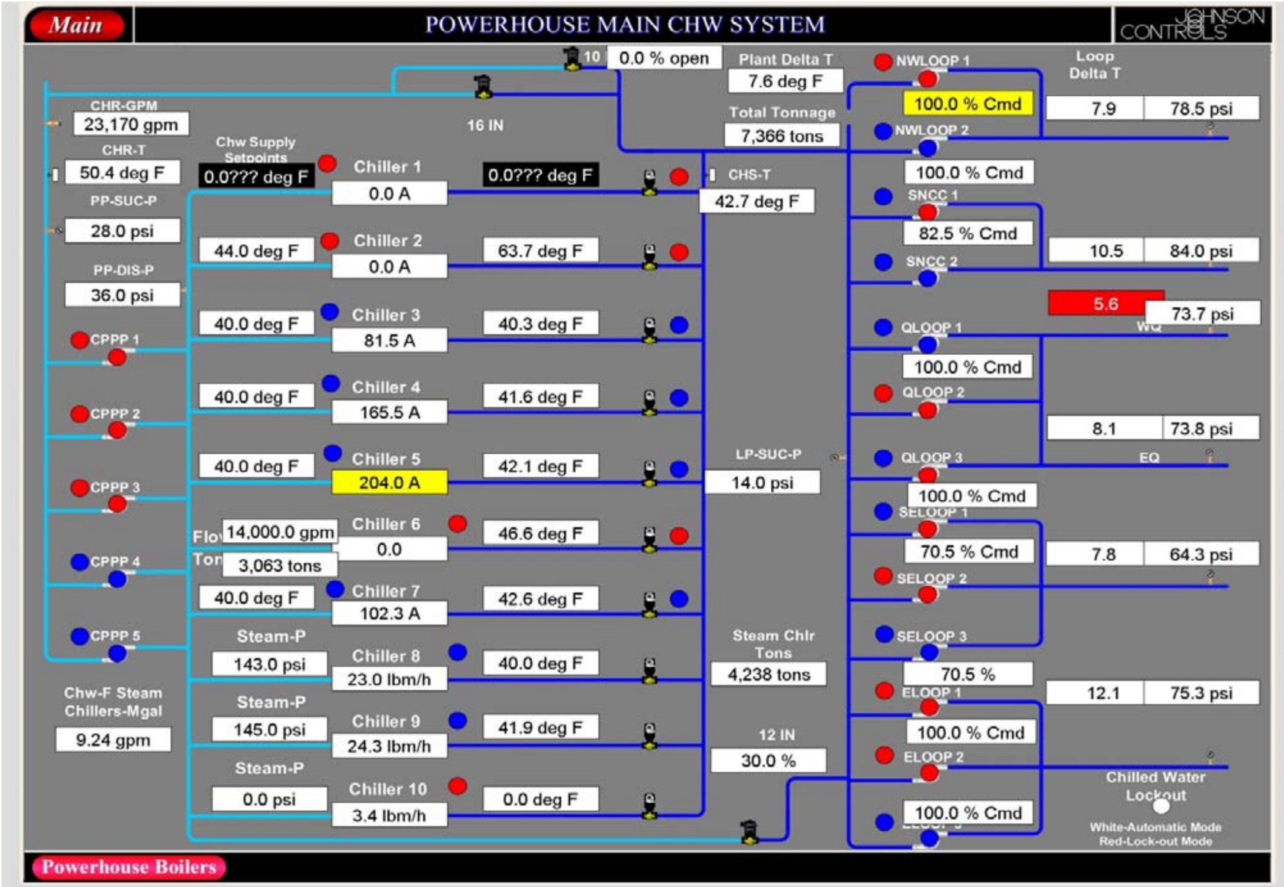

Figure CL-1: Central Plant Chilled Water Controls Graphics

The Highland Chilled Water Plant is interconnected and is operated in parallel with the Central Plant to serve the campus. The following summarizes the primary cooling equipment that is installed in

Electric Driven Chillers
1 – 1,100 tons
2 – 1,100 tons
3 – 1,500 tons
These machines are in relatively good condition. None have variable speed drives, which can reduce energy consumption.

At peak output in 2015, over 22,800 tons of cooling was produced and distributed on campus to nearly 70 existing buildings. Refer to the campus chilled water distribution map in the below Figure CL-2 for routing of the existing underground tunnels and piping. This distribution system totals over 4.5 miles and varies in quality. It has a very high leakage rate of over 10,000 gallons per day, the consequence of which is compensated for with expanded use of potable water that is treated before being used in the campus chilled water system.

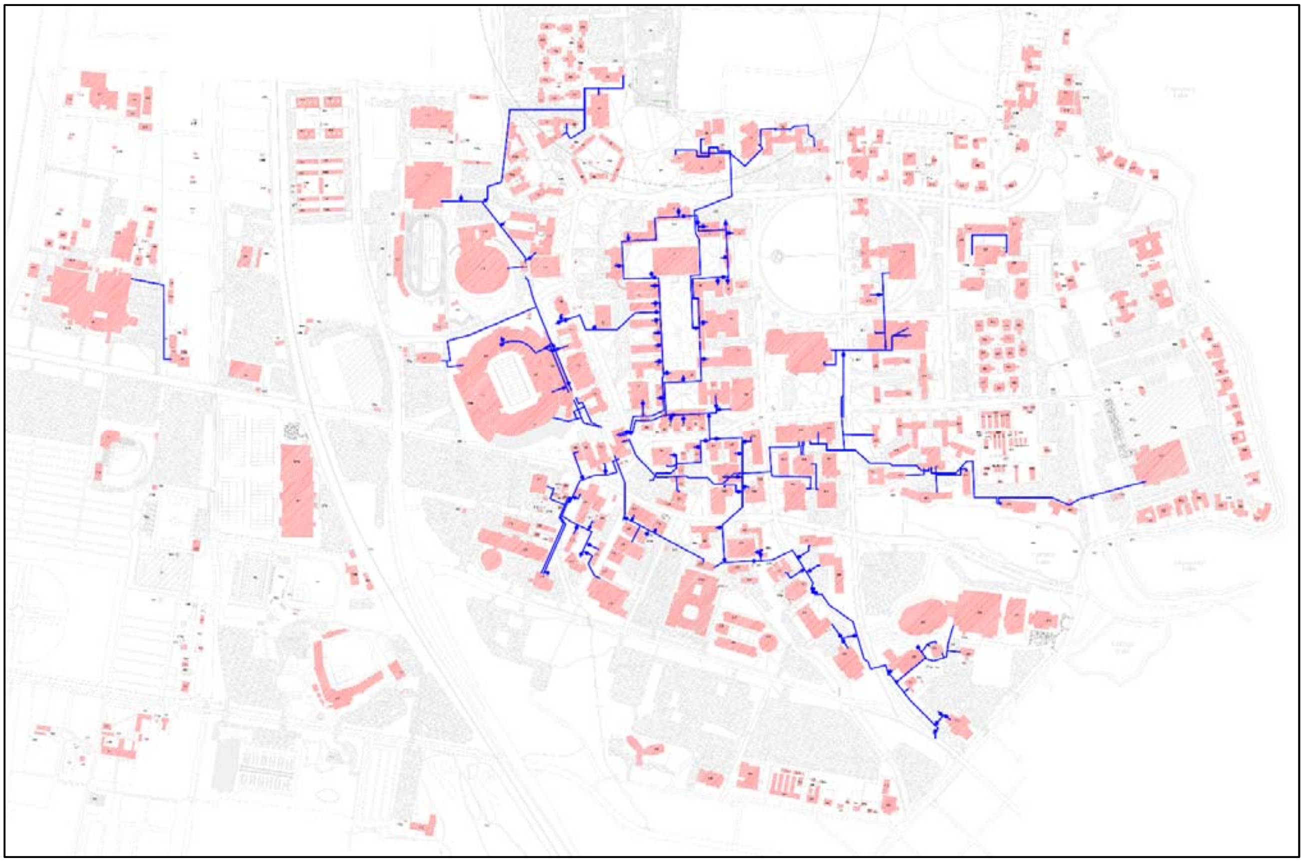

Figure CL-2: Existing Chilled Water Distribution Map

LSU has been replacing deficient sections of the chilled water distribution systems as practical, and expanding them where needed to serve new loads. The condition and largely radial based layout of the chilled water distribution system is illustrated in Figures CL-3 and CL-4, respectively. As the campus chilled water distribution system is expanded, the deficient lines should be replaced and the radial lines should be interconnected to create as many loops as is practical.

Figure CL-3: Chilled Water Distribution Condition Map – Under Development by LSU

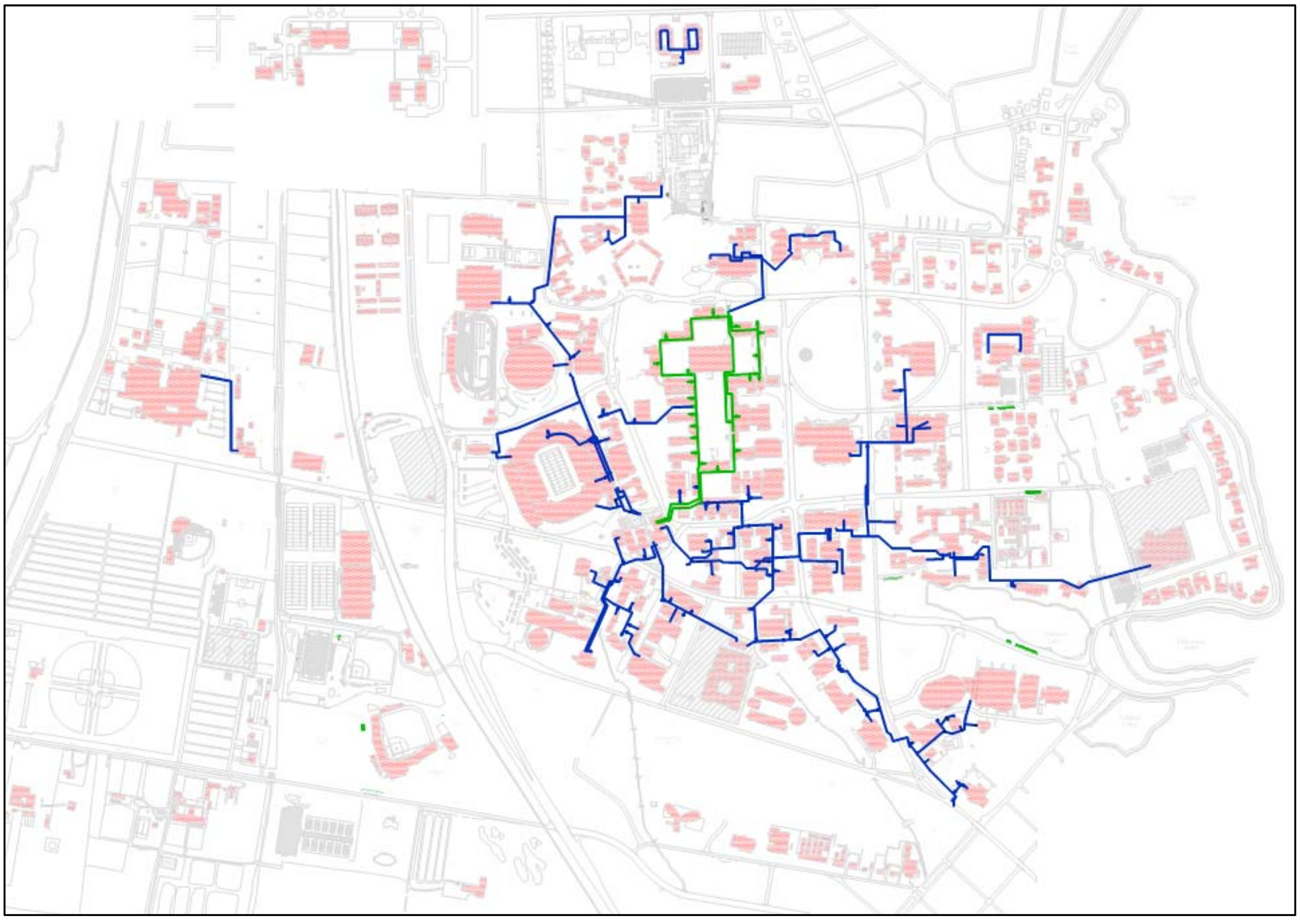

Figure CL-4: Chilled Water Distribution Radial versus Looped Piping Map

LSU currently does not have or maintain a hydraulic model for the chilled water distribution network This is a valuable tool for system management and maintenance.

The chilled water supply temperature to campus is typically maintained between 42°F and 46°F and the chilled water differential temperature (Delta T) is typically in the range of 10°F to 12°F. LSU has been modifying connected building controls and pumping as practical to improve the system Delta T and overall system efficiencies.

Chilled water consumption is metered at many of the existing buildings and monitored by the campus building automation system. There is a desire to add metering to all connected buildings. Non-academic buildings that are not equipped with meters are charged for chilled water use based on gross square footage and seasonal pro-rated hours of use. The academic buildings on campus are not metered and are not billed for their chilled water consumption.

Power System

In 2005, campus electrical distribution was upgraded to 13.8kV. This upgrade included the installation of a combustion turbine generator (CTG) at the Central Plant to operate in parallel with the local utility (Entergy) in providing power to the campus. The 13.8kV electrical distribution serves the legacy 4.16kV electrical distribution on campus via multiple substations. Five of these substations were replaced in 2005 when the campus switched its primary service from Entergy from 4.16kV to 13.8kV.

Since the upgrade to the electrical system, the Old Taylor Substation and Nicholson Apartments were added to the 13.8kV system via substation stepping down the voltage from 13.8kV to 4.16kV. More recently, the 13.8kV electrical distribution system has expanded to serve other parts of campus via step down transformers from 13.8kV to either 480V or 208V at West Stadium, the Union Expansion, Parking Deck, Dorms UREC Building and New Taylor Substation. The 13.8kV Entergy service in parallel with the CTG serves approximately 95% of the campus.

As it procures new equipment, the campus is transitioning to a 13.8kV distribution. New transformers installed on the legacy 4.16kV electrical distribution have dual primary ratings at 4.16kV and 13.8kV.

The Greek house buildings and some minor scale buildings on the northwest edge of campus have separate Entergy services. The Nicholson apartments will likely shift to a separate Entergy service in conjunction with implementation of a public/private structure for redevelopment of the apartments. Additionally, the south edges of campus currently fed from the legacy 4.16kV distribution, will potentially shift to separate Entergy services.

The following summarizes the Entergy substations located in proximity to the Central Plant:

Substation 1
69kV Primary
13.8kV Secondary
24/32/40 MVA

Substation 2
69kV Primary
13.8kV Secondary
24/32/40 MVA

The following summarizes the CTG located at the Central Plant:
13.8kV
18.7MW/22MVA

The peak campus electrical demand is approximately 35MW. The minimum campus electrical demand is typically approximately 20MW, but has reduced to 15MW on occasion.

The CTG is setup for kW import control which maintains a minimum utility kW demand of approximately 1MW at all times. At low campus demand loads the CTG reduces output to maintain this minimum utility kW demand. The arrangement with campus and Entergy is that the CTG may not export power to the utility grid.

Refer to the electrical distribution map in Figure EL-1 for routing of ductbanks throughout campus.

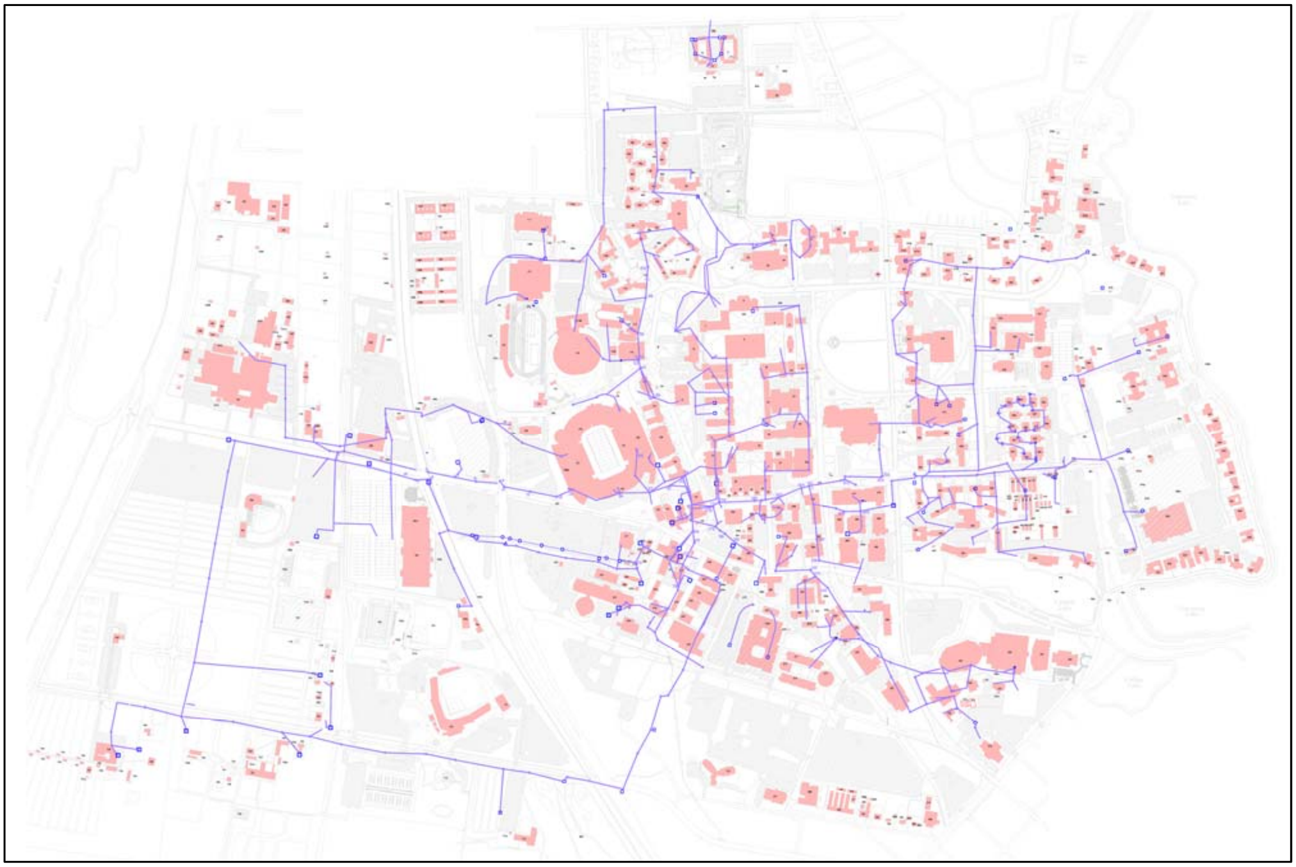

Figure EL-1: Existing Power Distribution Map

Refer to the campus electrical power one-line diagram drawings in Figure EL-2 (13,800V) and Figure EL-3 (4,160V). These indicate equipment age for newer installations. Equipment without ages are at least 15 years old with portions of the 4,160V system estimated at 30-40 years old. More legible, larger scale copies of these one line diagrams are also included in the Appendix.

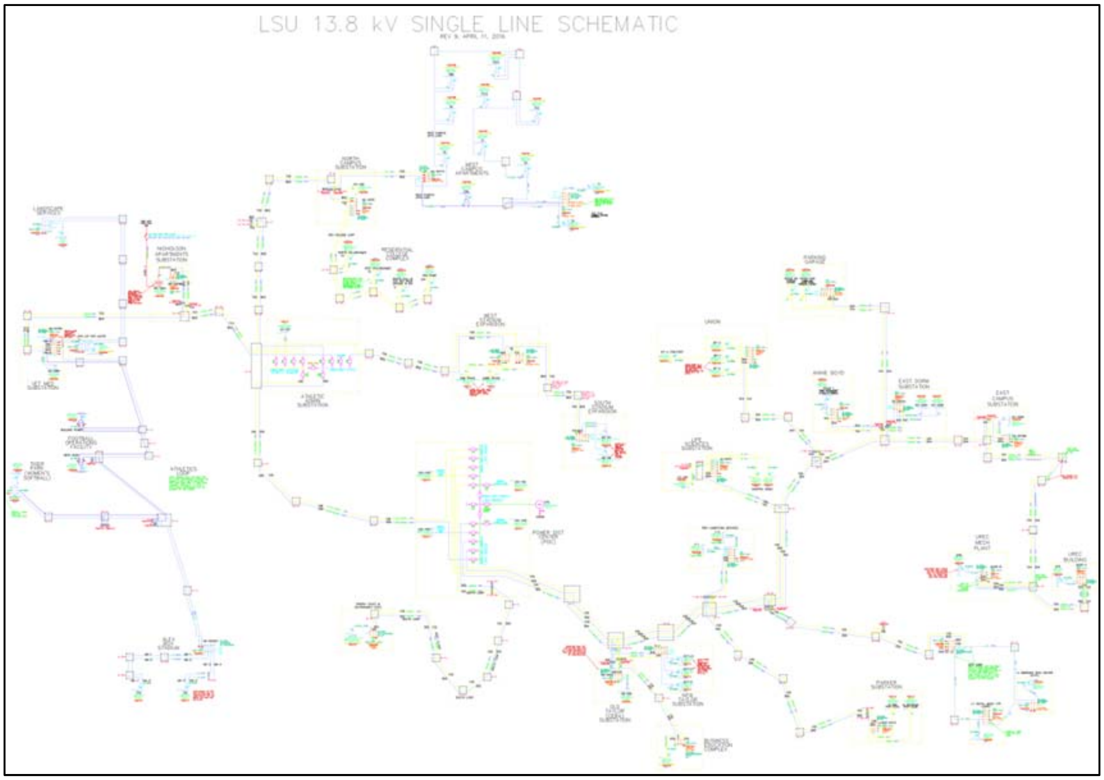

Figure EL-2: Existing 13,800V Power One Line Diagram

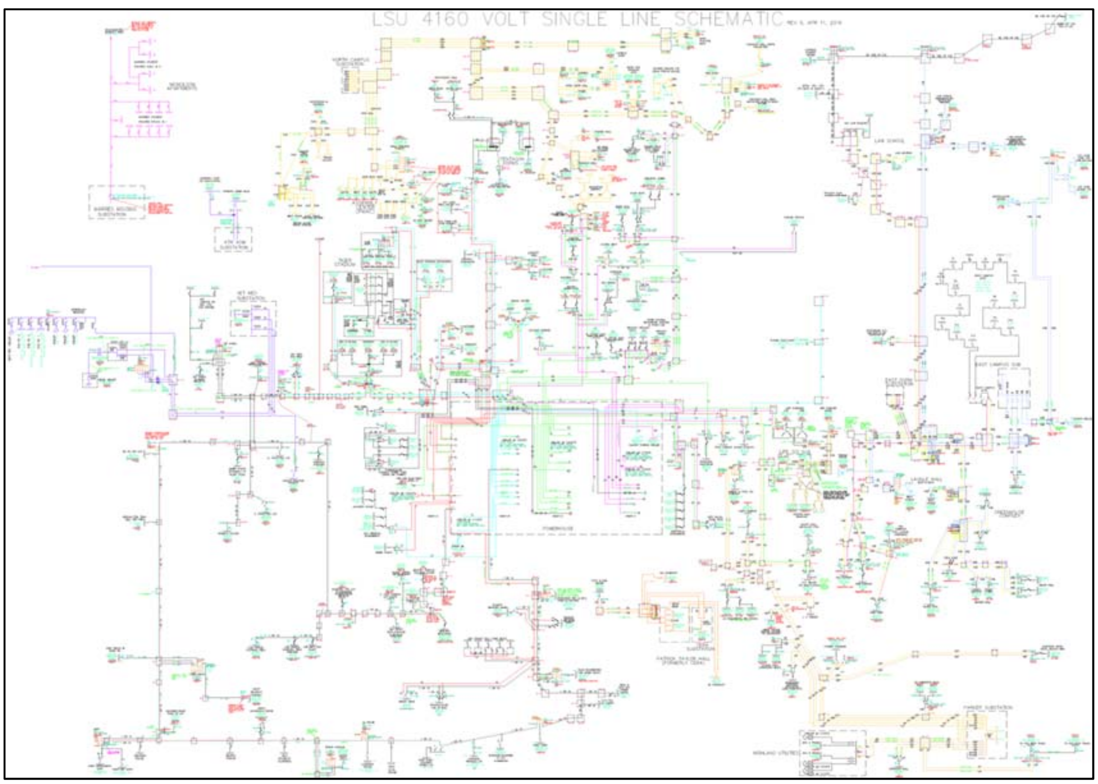

Figure EL-3: Existing 4,160 V Power One Line Diagram

System Deficiencies

The following summarizes the major deficiencies for the existing central heating, cooling and power systems that serve LSU.

1. Lack of heating capacity redundancy in the event of the loss of high pressure gas service.
2. Central Plant heating control system is aged and is failing.
3. Lack of steam distribution hydraulic model.
4. Lack of (or inaccurate) plant and building steam metering capabilities making efficient plant and building operations impossible to monitor, manage and control. There is no incentive to control or reduce demand in the buildings that are served and the plant is operated as efficiently as practical.
5. Steam and condensate distribution networks are in marginal condition. Repairs and/or replacement is needed throughout the system. This should include improved distribution network looping.
6. Lack of natural gas hydraulic model.
7. Lack of cooling capacity redundancy in the event of the loss of the largest chiller #6. N+1 chiller redundancy is recommended.
8. Many of the existing chillers are approaching or are at the end of their useful life and are in need of replacement. This includes all machines that are charged with R-11 and R-22 refrigerants which are no longer produced due to their negative environmental impacts. Variable frequency drives should be evaluated to be included with any new chillers if economically viable.
9. Many of the existing cooling towers are approaching or are at the end of the useful life and need replacement. The metal packaged cooling towers associated with the electric centrifugal chillers are well beyond their useful life and need immediate replacement. Variable frequency drives should be included with any new tower cells.
10. The condenser water systems in the Central Plant are piped independently such that they cannot be shared between the various chillers which greatly reduces the system operational flexibility and reliability. Interconnect/manifold the various hydraulically isolated groups of cooling towers at the Central Plant.
11. Central Plant cooling control system is aged//failing and is due for replacement.
12. Lack of, or inaccurate, plant and building chilled water metering capabilities frustrate the possibility of efficient plant and building operations. There is no incentive to control or reduce demand in the buildings that are served and the plant is operated as efficiently as practical.
13. System Delta T’s are low resulting in poor system efficiencies.
14. Lack of chilled water distribution hydraulic model.

15. A strategy is needed to serve the northwest precinct of campus with central chilled water. A new chilled water plant could be considered due to perceived limitations in the existing distribution system.

16. The chilled water distribution network has a very high leakage and make up rate. Repair/replacement is needed throughout the system including the creation of more strategic loops in the system.

17. Much of the legacy 4.16kV distribution equipment is at or reaching the end of its service life and in need of replacement. The practice of replacing this equipment and shifting the distribution to 13.8kV should continue.

18. Within the legacy 4.16kV cabling distribution there has been failures with T-splices. The practice of avoiding these splices and utilizing sectionalized switches instead should continue.

19. Lack of electric metering at academic buildings.

20. Minor capacity concerns for feeder pairs 105/305 and 104/304. Feeder 105/305 requires both feeders to be active when operating all electric chillers. Feeder 104/304 is approximately 70-80% loaded. These feeders should not be relied for additional load increases on campus.

21. The southwest portion of campus is fed from a single electric feeder loop (1/19) on the 4.16kV distribution and is the greatest capacity concern.

Future Considerations

Based on planned growth and the utility system deficiencies identified during this campus Master Planning process, it is recommended that LSU commission a comprehensive energy and utilities Master Plan. This plan would be charged with inventorying and detailed evaluation of the existing systems, detailed load projections, system operational and hydraulic modeling, identification and comparative analysis of various options for upgrading and expanding the existing systems while reliably and efficiently serving the existing campus and all planned growth, and establishment of related budgets and implementation timelines for these improvements. It would represent a needed “road map” for the reinvestment and expansion of the university’s energy and utilities systems.