Nanogrid Electrical Design and Analysis

by

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Senior Project

ELECTRICAL ENGINEERING DEPARTMENT

California Polytechnic State University

San Luis Obispo

March 2015

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Acknowledgements

I would like to thank Professor William Ahlgren for giving me the opportunity to work on an interesting and useful project for this campus. I would also like to thank Rex Wolf and Ben Johnson for providing the necessary information and assistance from Facilities. Finally, I would like to thank my friends and family for supporting me throughout my college career.

Abstract

Power plant generators have quality protection over long-range transmission, but localized generation interacts with multiple power sources, and needs maintenance to ensure grid safety. Localized and distributed generation must solve these issues to remain viable economically and efficiently in power industries. Cal Poly's Building 20 provides on-campus location to interconnect renewable generation with interconnection disconnect capabilities.

Cal Poly's grid includes three localized generators flowing through the Cal Poly substation. Unlike other universities which use power from utilities across distant transmission lines, Cal Poly generates energy using onsite generators. Research including additional possible sites of power generation helps determine the effects on campus power distribution. Better analysis of facilities capable of lab voltage distribution systems (LVDS) combined with studies of nanogrid interconnections ensures better comprehension of microgrid technologies.

I. INTRODUCTION

Power systems integrate Cal Poly's facilities, from the first turn-of-the-century steam engines, to present-day cogeneration systems. Cal Poly power usage requires distributed systems, such as cogeneration systems for housing, PV generation from Engineering West, and bulk of off-site power from Mustang Substation. Cal Poly needs to expect greater further distribution generation.

Traditional power systems rely upon century old hierarchical power plants sending HV transmission lines to substations which transform HV for compatible consumer usage. Cal Poly uses this and distributed generation, cogeneration and PV arrays, which play significant roles in microgrids. The microgrid involves a single link for energy travel between the distributed generation grid and the off-site national grid. Microgrids have the ability to seamlessly connect and disconnect the single link while providing a cluster of generators equivalent to a flat distribution of power. Yet, Cal Poly lacks a microgrid as most energy needs comes from off-site generation through Mustang Substation.

Imagine extensive fires, flash floods, or even terrorist attacks endangering a transformers or generator of traditional power stations. All consumers below this point on the top-down hierarchy lose power, but microgrids have the ability to supply power and receive power due to flatter distributed generation. When one distrusted generator shuts down, the microgrid connects to the main grid to offset losses or even vice-versa. Though PG&E prevents the campus from supplying to the national grid, Cal Poly paves the way with future distributed generator development on the long-term.

Cal Poly State University needs further analysis of the campus protection grid to develop in the long-term more self-sufficient, renewable and reliable generation. Using CAD software, SKM Power Analysis Tools focuses upon designing and analyzing Building 20's electrical engineering facilities. The goal of determining Cal Poly's effective power system establishes groundwork for further distributed generation to simulation a microgird within the campus. The goal is to study nanogrid technology from onsite generation under better energy efficiency using LVDS interconnections.

II. REQUIREMENTS & SPECIFICATIONS

Cal Poly State University needs further analysis of the campus grid to ensure the protection systems work adequately under distributed and transmitted sources. When distributed generators were built on Cal Poly, campus operations needed to insure underground power lines maintain the same protection when running with off-site generation [3]. Unfortunately, analyzing protection grids after constructing new sources, like the Sierra Madre cogeneration plant, in power systems engineering requires capital, time, and bureaucracy. Therefore, simulations focus on design and analysis by giving an accurate measurements or refining the system simulated as skills improve until reducing the expenses of rectifying errors after testing [1][2]. If simulations ensure proper protection under fault conditions, Cal Poly can focus on further development of distributed generator power through a simulated microgrid in the form of an actual nanogrid.

Another goal of using more generators reduces utility transmission and distribution costs, but not at the expense of new generation implementation costing more than the price of lifetime power generation. Ultimately, Cal Poly participates in CSU's system, and the CSU system requires generating at least 26MW distributed power, preparing for California's future energy consumption. The product simulates the campus grid including generators using Facilities' permission to determine power system effectiveness. After schematic completion, further simulation creates fault lines around protection relays, helping determine the power protection component's effectiveness. An additional analysis is required to determine whether the facility used will have the ability to install distribution generation to simulate a microgrid in the LVDS.

TABLE I

SENIOR PROJECT REQUIREMENTS AND SPECIFICATIONS

Marketing Requirements	Engineering Specifications	Justification
1	Simulate facility in conjunction with substation campus operations.	Advisor suggested entire campus gird already determined, but needs generation's effects on grid protection.
2	The simulation must indicate protection relay operates when fault sensed.	Cal Poly's Sustainability Page and Jaideep Gill's line measurements.[1] [2]
3	Analysis of Building 20 design schematics to determine optimal input for DG.	To avoid disruptions within the power system of Building 20 for simulation of nanogrid.
4	Simulation uses Mustang Substation voltage output and operates in in grid.	CSU Executive Order 987 compliance. [3]
5	Reduces PG&E's power usage & new generation safely provides lifetime energy price > implementation costs.	Following grid protection requirements & Cal Poly's 2009 annual power bill using sustainability webpage.[3]

Marketing Requirements

1. Simulations implement accurate generation sources.
2. Simulation indicates protection systems preventing faults.
3. Simulation determines generation and transformer inefficiencies.
4. The simulation adheres to university and utilities organizations policies.
5. If feasible from simulation, the economics implementing the nanogrid though distributed generation attached to LVDS of Building 20.

TABLE II

SENIOR PROJECT DELIVERABLES

Delivery Date	Deliverable Description
04/03/2014	Design Review
04/15/2014	Completion of On-Site Visit & Analysis
05/6/2014	EE 461 Demo I1
06/02/2014	EE 461 Report
05/26/2014	EE 461 Demo I2
03/15/2015	ABET Sr. Project Analysis
03/20/2015	EE 462 Report

[1] R. Ford and C. Coulston, *Design for Electrical and Computer Engineers*, McGraw-Hill, 2007, p. 37

[2] *IEEE Std 1233, 1998 Edition*, p. 4 (10/36), DOI: 10.1109/IEEESTD.1998.88826

III. Functional Decomposition (Level 0 & 1)

Figure I. Level Zero Black Box SKM Simulator Diagram

TABLE III
ZERO LEVEL BLACK BOX DELIVERABLES

Module	SKM Power Analysis Simulator
Inputs	- Campus Grid Power Data - Transformer Data
Outputs	- Power Consumption and Protection Using Fault Analysis - Recommend Future Possible Campus Power Generator Specifications
Functionality	Input the data using campus Facilities' resources [6] and research using SKM Power Analysis Simulator [1] [2]. The output schematic design and power/protection analysis results in extraneous generator design with SKM analysis determining plausible forms of efficient campus power generation.

The level zero block diagram has two inputs and two outputs. This system uses the SKM Power Analysis Simulator when designing the core data inputs and analysis. Using rated onsite generators and grids input from Figure I, the power usage and power protection effectiveness becomes discernable. This fairly simple black box, explained using Table III, further expands under the Figure II first level block diagram below. This new diagram contains two modules and simulates power generation including loads. To satisfy level 0 requirements, feedback between the two modules becomes necessary, determining how power flow regulates simulated faults through module #2. The 12.4kV campus voltage, along with 70kV power through the substation uses Cal Poly's Sustainability page under campus power needs. Exact campus grid data, i.e. number of buses, line voltages, fault currents, phases, etc., refined later upon overall design completion. Using Table IV and V block diagram description, substation transformers reduce power by a factor seen in Equation 1.

$$\frac{70kV}{12.4\ kV} = 5.65 \sim 14.28 = \frac{70kV}{4.9kV} \qquad (Eq. 1)$$

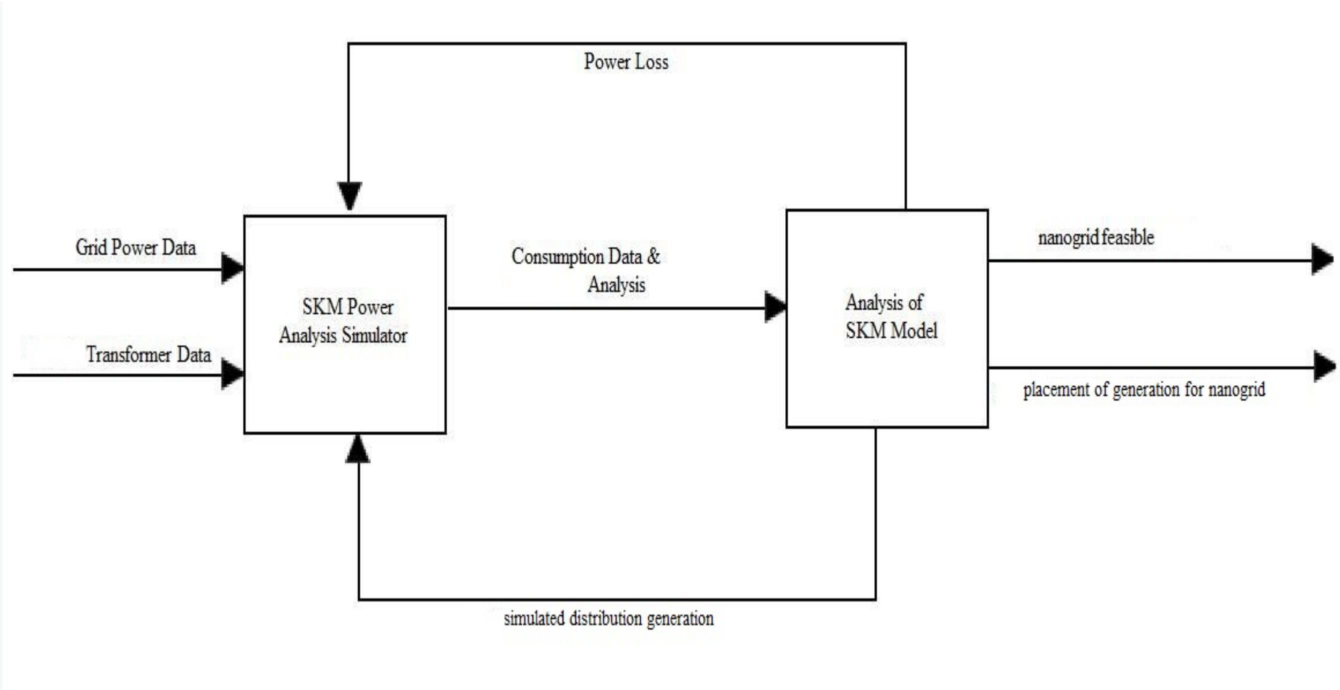

Figure II. Level One Black Box SKM Simulator Diagram

TABLE IV

LEVEL ONE BLACK BOX DELIVERABLES

Module	Simulated Power Supply
Inputs	- Generation Input, PV Generation Input, & Substation Power 12kV - Feedback of Power Loss, Fault Lines, or System Issues
Outputs	- Campus Building 20 Power Analysis: ~ 480V[3] - If Extraneous Generator Feasible Under Production and Protection Costs
Functionality	Simulated Power Supply takes in Generator Data and pushes through transformers voltage within Simulated Power Grid Range. Feedback adjusts supply during line faults, and if extraneous generators added, informs system of new power grid loads. [1][2]

IV. Design Schematics

Figure 3. Building 20 Engineering East Room Map

Figure 4. Position of Lab Voltage Distribution System Panels within Building 20

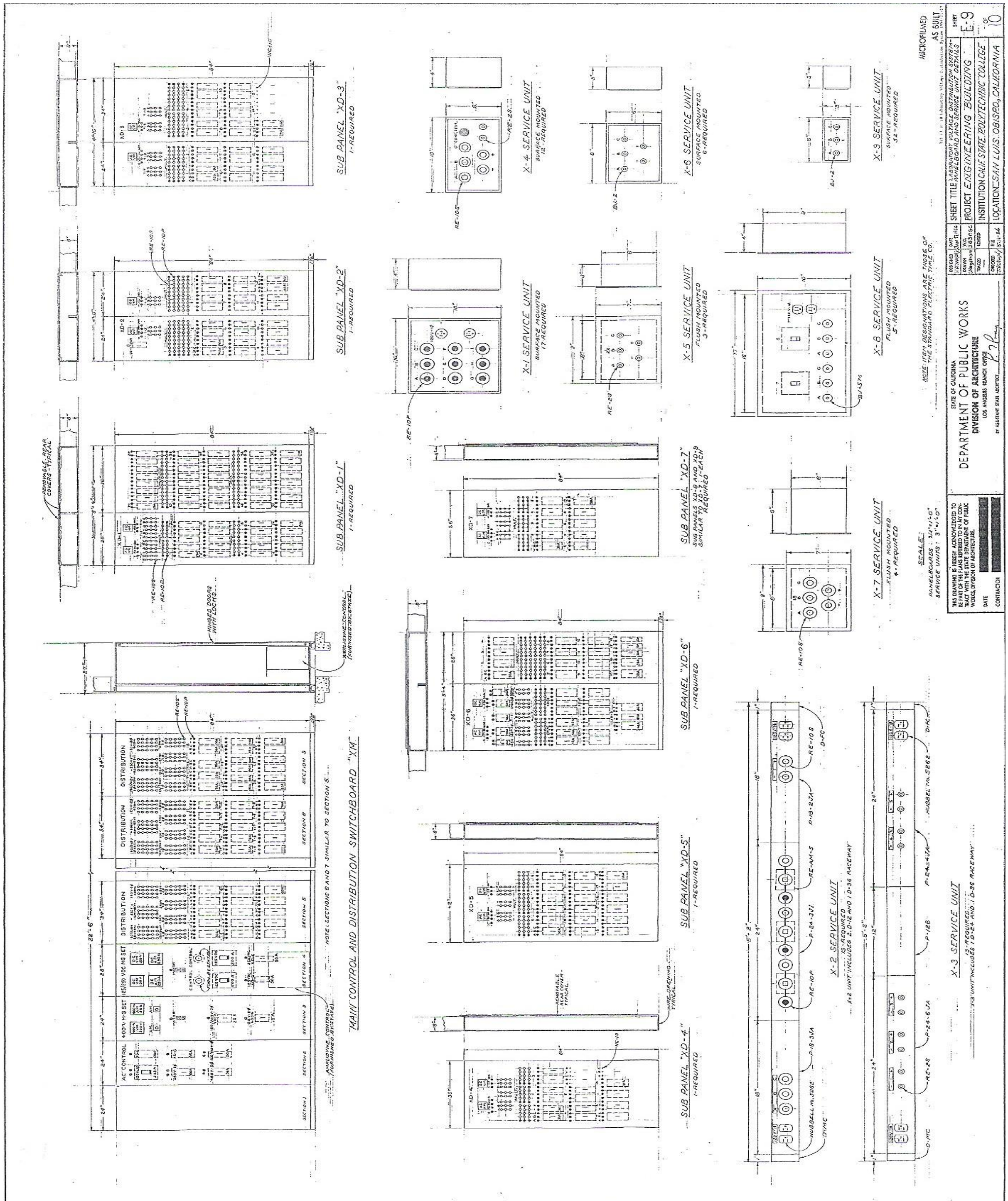

Figure 5. Lab Voltage Distribution System Panels within Building 20

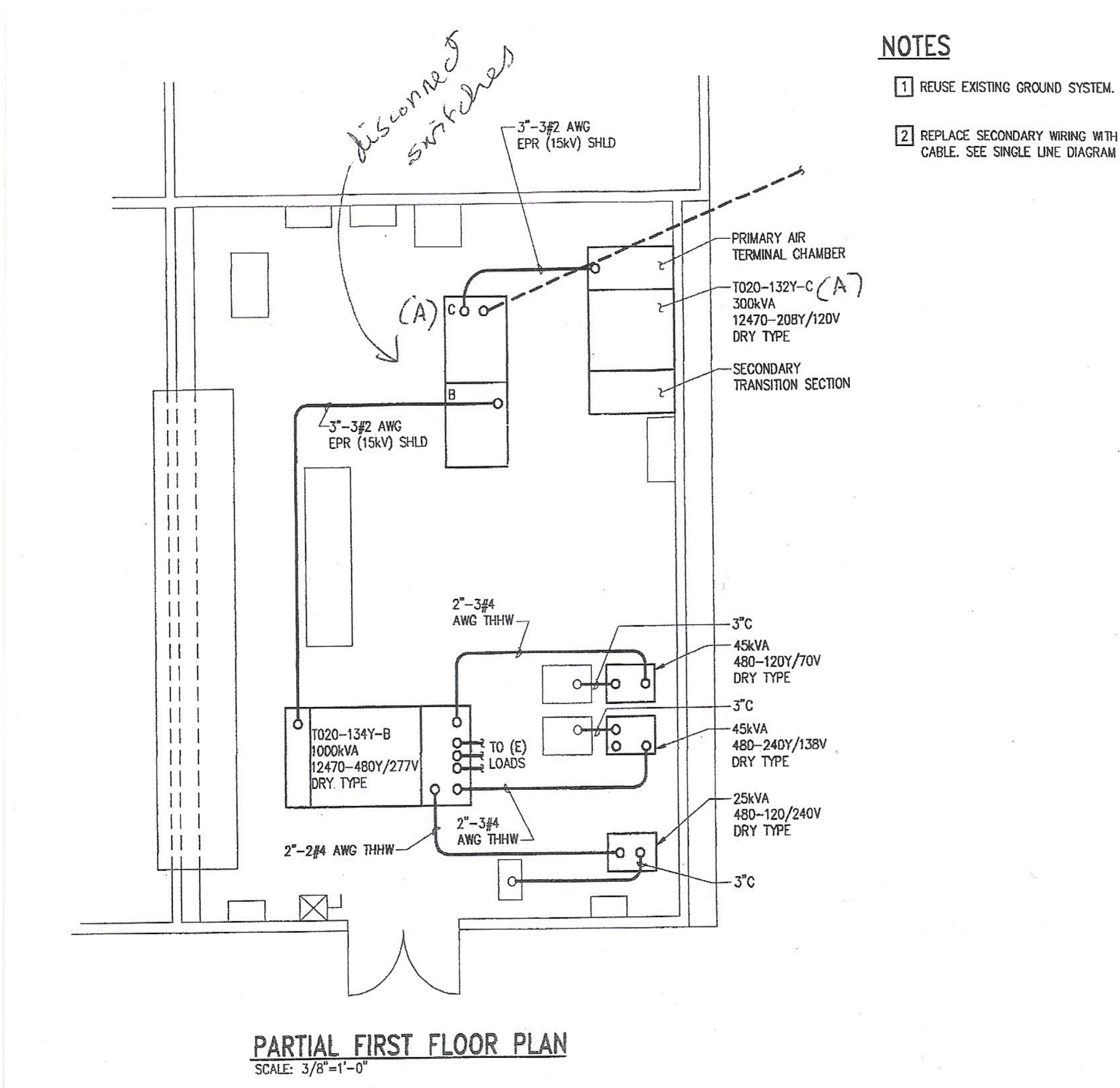

Figure 6. Transformer Room (20-103) within Building 20

Figure 2 and 3 contain LVDS panels removed or updated throught the 1990 remodelling process. Though verifiying which panels continue to exist behind plaster or completely removed, plans for a distribution system may move forward, particularily in the north side of Building 20. Thus, some of the panels show within Figure 5 don't exist presently, while main switchboard XM still exists within 20-102. All existing panels currently connect from feeders through the 12.47kV/480V transformer, as seen in figure 6. A disconnect in 20-103 allows for interconnection between the 12kV cable from Mustang Substation and the transformer room of Building 20, which supplies all power to smaller transformer windings.

B20 Electrical System Drawings

As seen from the Appendix A drawings, these plot plans and schematics were analyzed to determine how the 1990 remodelling affected the cables and interconnections to the laboratory voltage distribution system. All these rooms are defined in Appendix B for purpose and defines department usage.

- **020 E-1 of 10** Plot Plan + Feeder Diagram 1956 – 01 – 27

This list shows how power feeds into B20 from the campus distribution system. Also shows electrical equipment in 20-103 (the B20 electrical services room). It is out-of-date because a major upgrade of the campus power distribution system occurred in the 1990's.

- **020 E-4 of 10** Lighting + Power Unit 3 1956 – 01 – 27

This shows a floor plan of the transformer room (20-103) with list of equipment in it. Currently out of date!

- **E-10 E5.17** Electrical Equipment Plan 1996 – 02 – 16

This show the change to 20-103 in 1996, but is still not necessarily correct for what is in place today.

- **020 E-5 of 10** Misc. Elec. Sys. Unit 1 1956 – 01 – 27

This shows the LVDS as – built in the North – most portion of B20.

- **020 E-6 of 10** Misc. Elec. Sys. Unit 2 1956 – 01 – 27

This show half of the Laboratory Voltage Distribution System (LVDS) as-built in 1956.

- **020 E-7 of 10** Misc. Elec. Sys. Unit 3 1956 – 01 – 27

This shows the other half of the LVDS.

- **020 E-8 of 10** Schematic Feeder Diagram 1956 – 01 – 27

This shows how the as – built LVDS panels were interconnected.

- **020 E-9 of 10** Lab. Volt. Dist. Sys. 1956 – 01 – 27

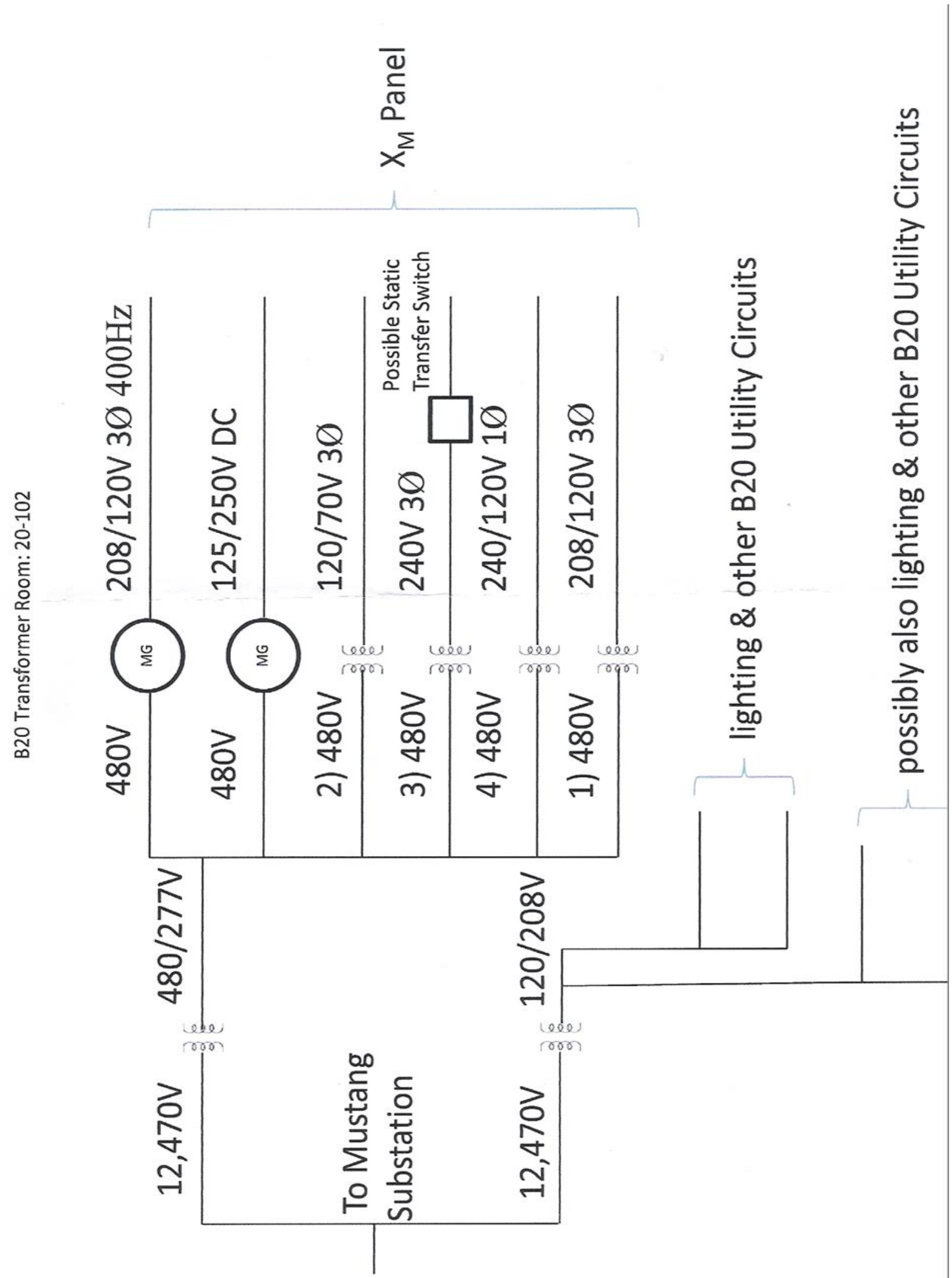

Figure 7. Schematic of Electrical System within Transformer Room to LVDS Panels and Misc.

Figure 7 indicates the transformer room supplies the main switchboard XM, with 480V secondary voltage from the main transformer to primary side of delta to wye winding in switchboard voltages. As the 12.47kV cable also supplies lighting and non-LVDS powered sources, this schematic previews power generation from distributed generation. The alternate source of power, from PV arrays, can supply though

disconnects to the main switchboard or other exisiting panels as a test of simulated microgrid, or nanogrid technology separate from the mustang substation.

V. Analysis of SKM Model

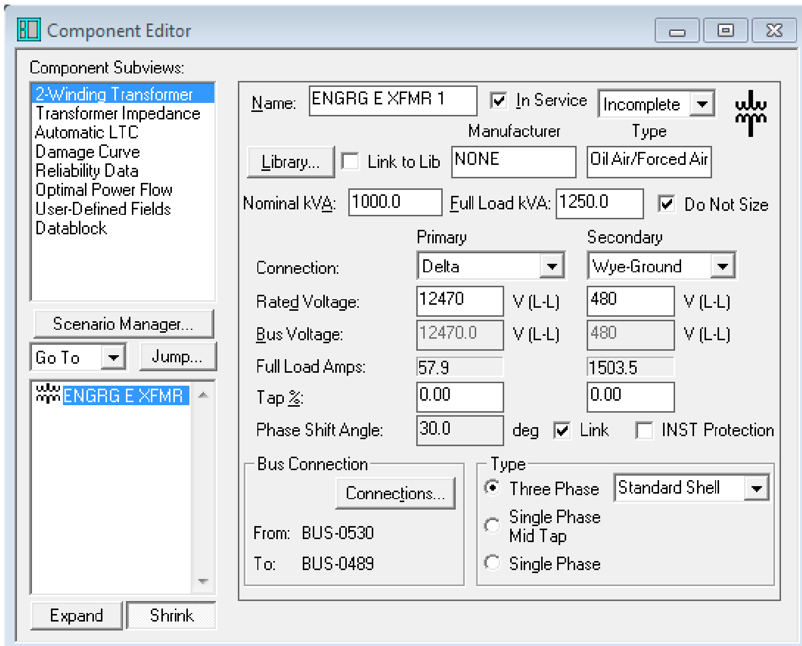

Figure 8. Software Picture 1- Transformer Room Rated Voltage Characteristics

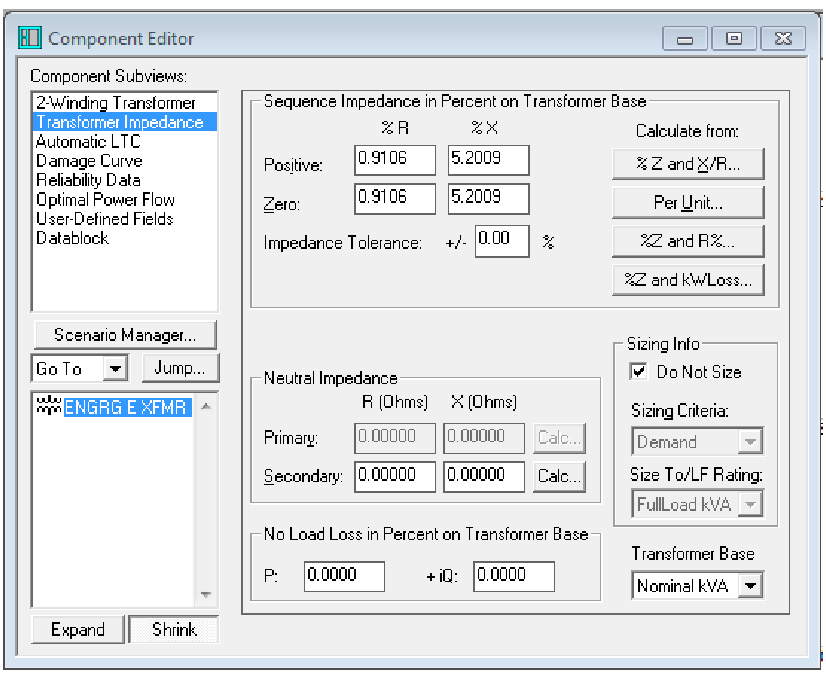

Figure 9. Software Picture 2- Transformer Room Impedance Characteristics

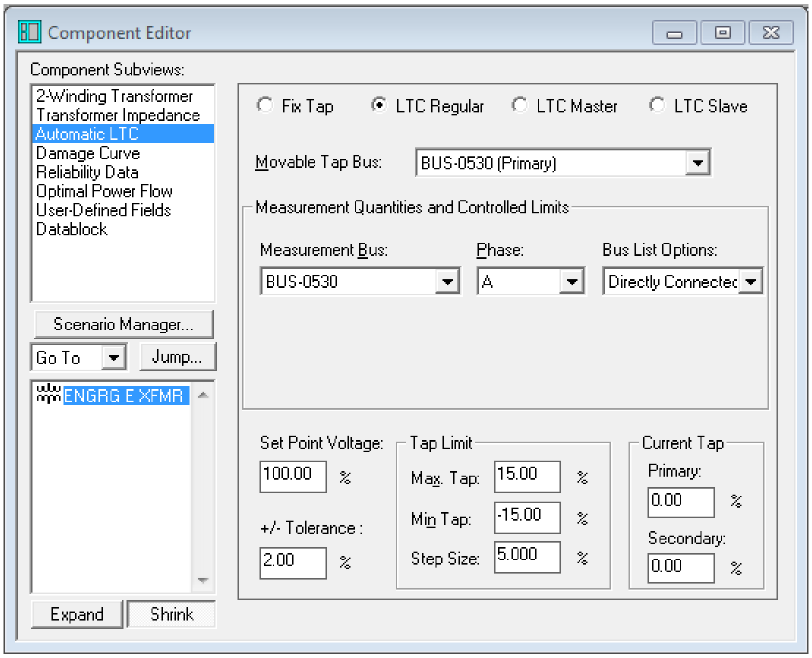

Figure 10. Software Picture 3- Transformer Room Bus Characteristics

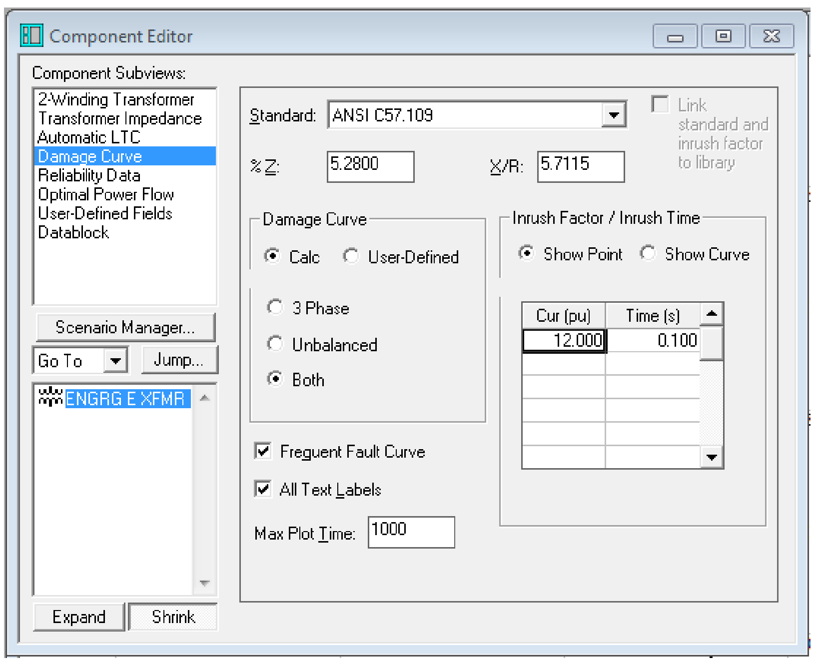

Figure 11. Software Picture 4- Transformer Room Overload Capability Characteristics

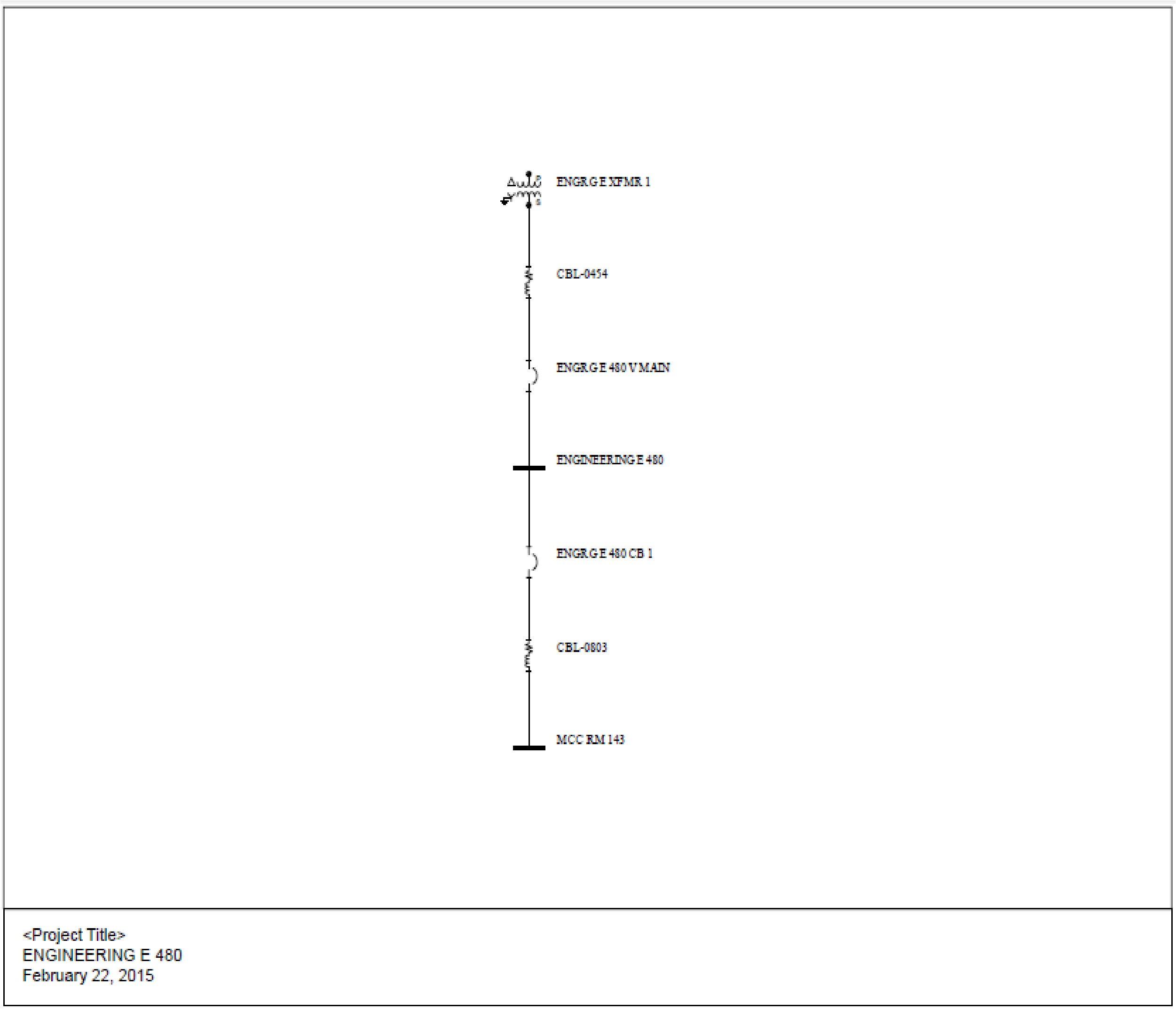

Figure 12. Software Picture 5- SKM Schematic of Transformer Room to Xm Panels

As transformer room transformer characteristics are defined (Figure 8-11) using the known Energy E brand and given ratings to create a 12.47kV/480V component within SKM. Figure 6 defines cable size and phase, including nominal kVA ratings and rated primary to secondary voltages. Internal impedances also indicate why kVA instead of kW ratings are used due to reactive power losses within the transformer. The inclusion of damage curve data indicates the capabilities of the transformer before failure due to overcurrent loads causing faults within the system.

Figure 12 needs further load analysis in the future given the information of circuit breakers within the transformer room, and further circuit breakers from the transformer room to LVDS or lighting within Building 20. Load and fault analysis would further determine the amount of distributed generation on the building necessary to generate a nanogrid output within Engineering East.

VI. Conclusion

This project analyzed whether, through SKM and plot plan designs, Engineering East is capable of producing a microgrid on campus. Though in essence a microgrid cannot exist presently on Cal Poly's campus, distributed generation through a PV array can supply power through new cables through existed ducts underneath Engineering East. These cables have the ability to connect through to the XM panel, or to any of the existing panels, labeled as removed, but may only have been plastered over with pre-1990 model cables removed. Thus, a separate, miniature grid exists in parallel with the main campus grid, and the inclusion of interconnections to Engineering East's grid will allow for nanogrid studies for electrical engineering students. Yet, more studies and simulation of types of distributed generation must occur for more concrete details into the formation of a nanogrid. Issues involving amount of power generation using PV arrays within north side of building 20, along with interconnection to 480V primary voltages through the LVDS needs more analysis, using upcoming electrical engineering graduates and undergraduates.

VII. References

[1] Jaideep Gill, "*Poly Canyon Cogenerational System*", Dept. Elect. Eng., California Polytechnic State University, California 2011. Avaliable: http://digitalcommons.calpoly.edu/eesp/123/

Report implements generation systems in Poly Canyon, and research enables further analysis of other cogeneration systems on campus. Authority comes from Professor William Ahlgren though advising and guiding senior project with power system emphasis. Currently, report on Google Scholars, but not cited presently.

[2] Minesh D Patel, *"Cal Poly Power System Design and Analysis"*, Dept. Elect. Eng., California Polytechnic State University, California 2011. Available: http://digitalcommons.calpoly.edu/cgi/viewcontent.cgi?article=1090&context=eesp

Senior project report initializes campus grid design simulation with more emphasis on interconnections than power protections, and useful to prevent reinventing extensive campus simulation. Authority gained from reviews with Professor Amhad Nafisi and William Ahlgren, both Cal Poly professors involved in power systems.

[3] Unkown. (2014, Febuary 3) Campus Operations [Online] Available: http://afd.calpoly.edu/sustainability/campusoperations.asp?pid=5.

Website enables resources and figures from Cal Poly Facilities informing reader of basic energy and electrical operations during an annual basis. Authority uses Cal Poly's Administration and Finance Department from main website as facilities subset.

APPENDIX A. E5-57 of 10: Lab Voltage Distribution System Floor Plans

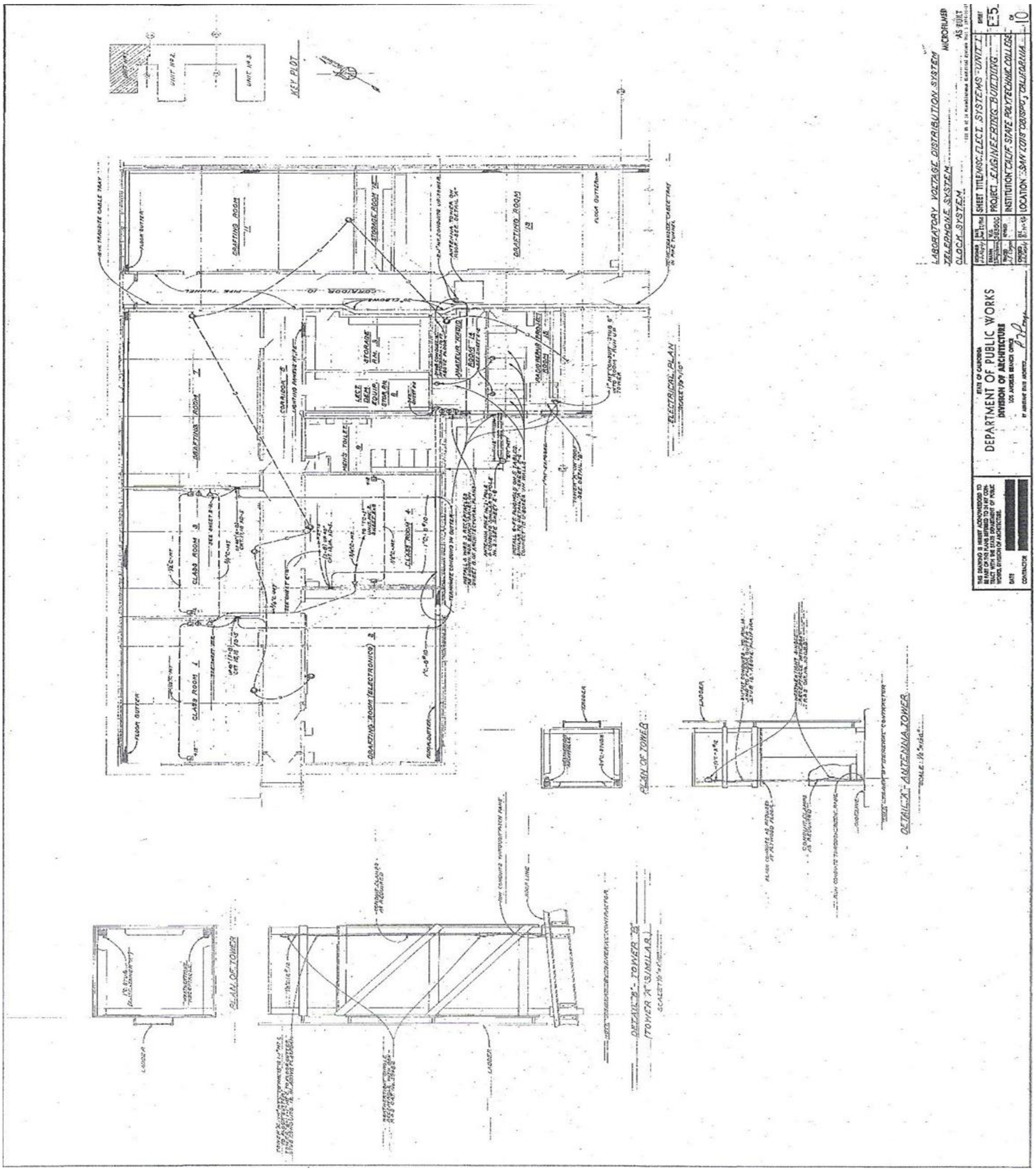

Figure 13. E-5 - Electrical Plot Plan North Building 20

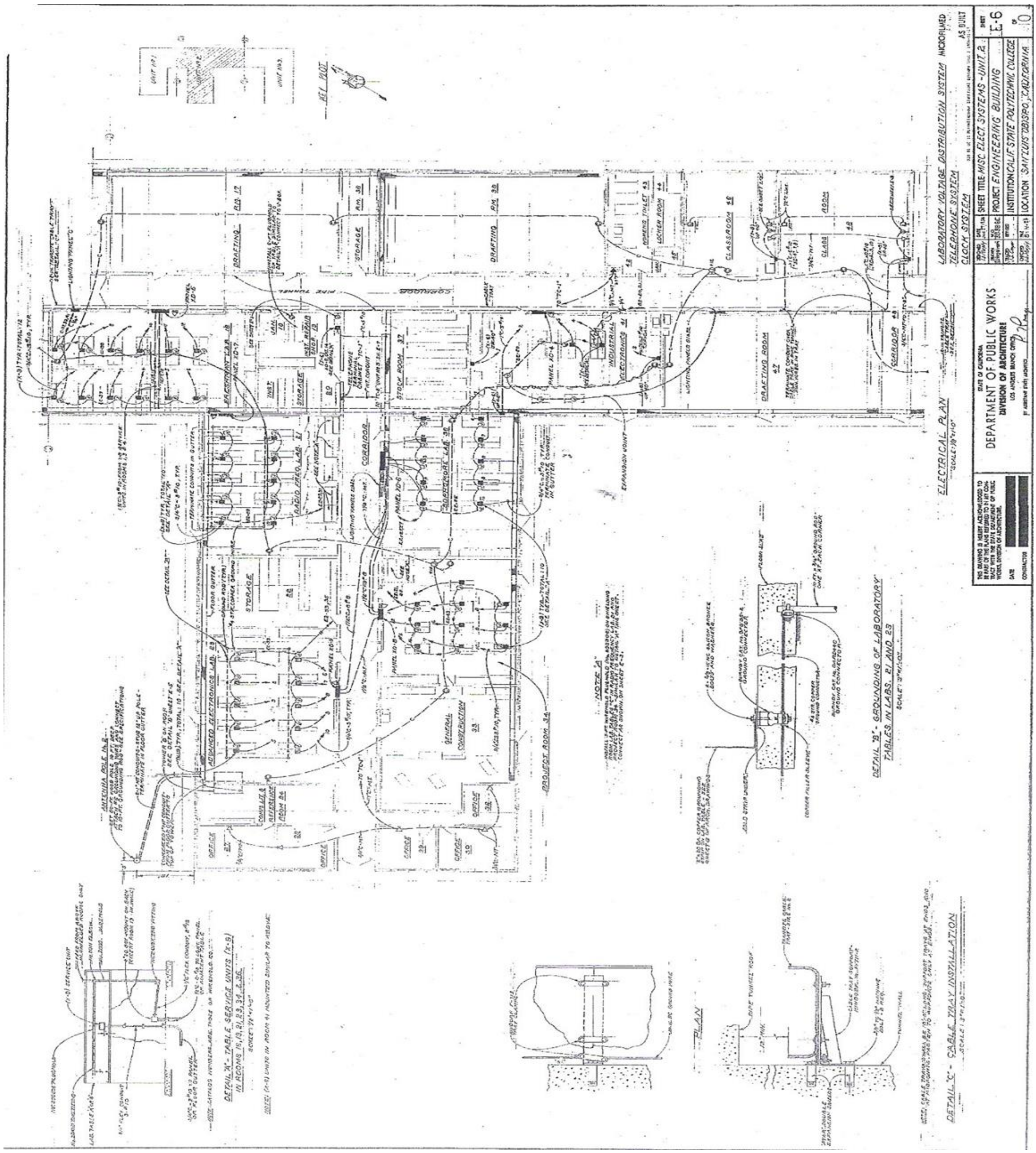

Figure 14. E-6 - Electrical Plot Plan Central Building 20

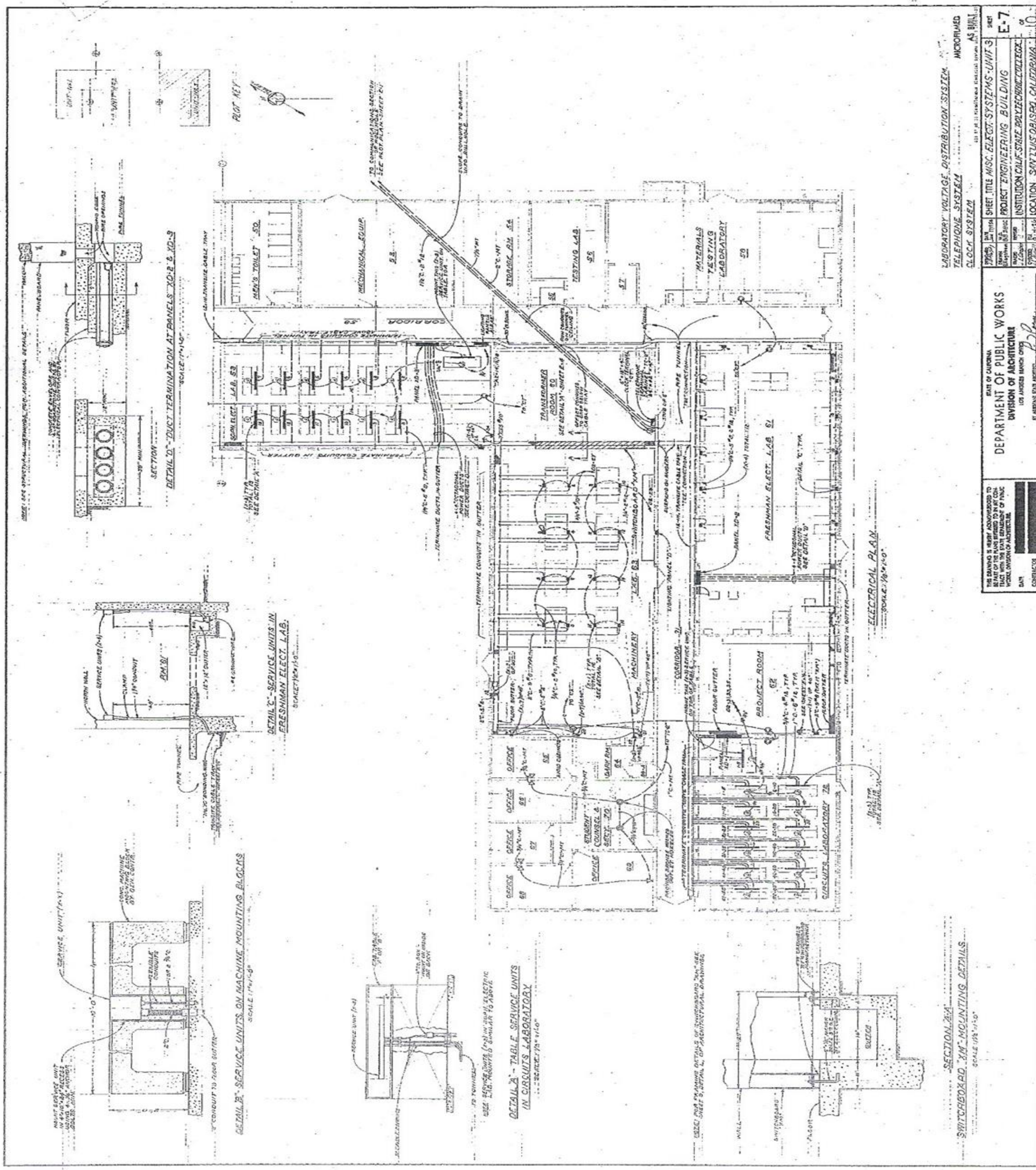

Figure 15. E-7 - Electrical Plot Plan South Building 20 Containing Transformer Room

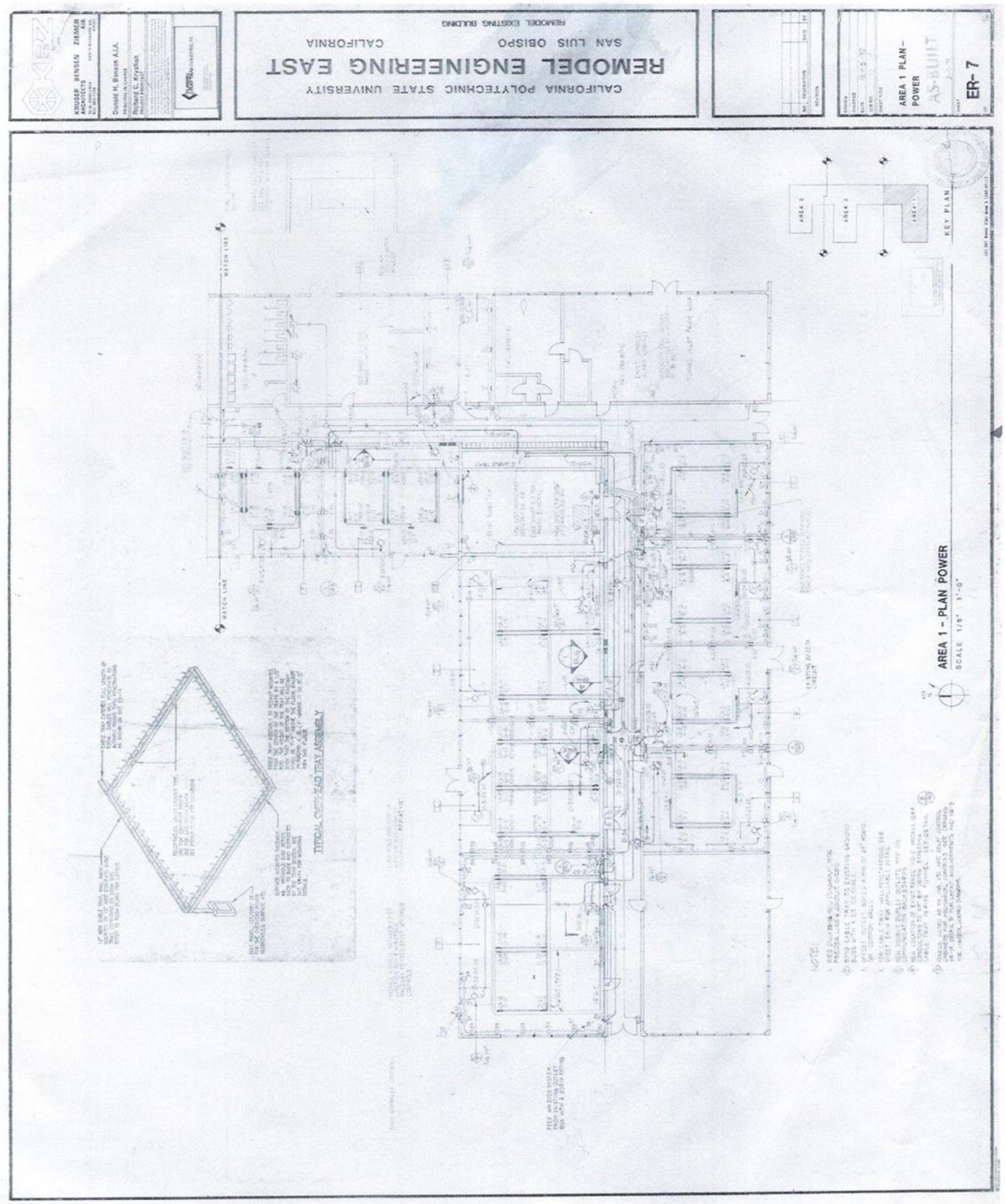

Figure 16. 1990 Remodel Lighting and Construction Plot Plan

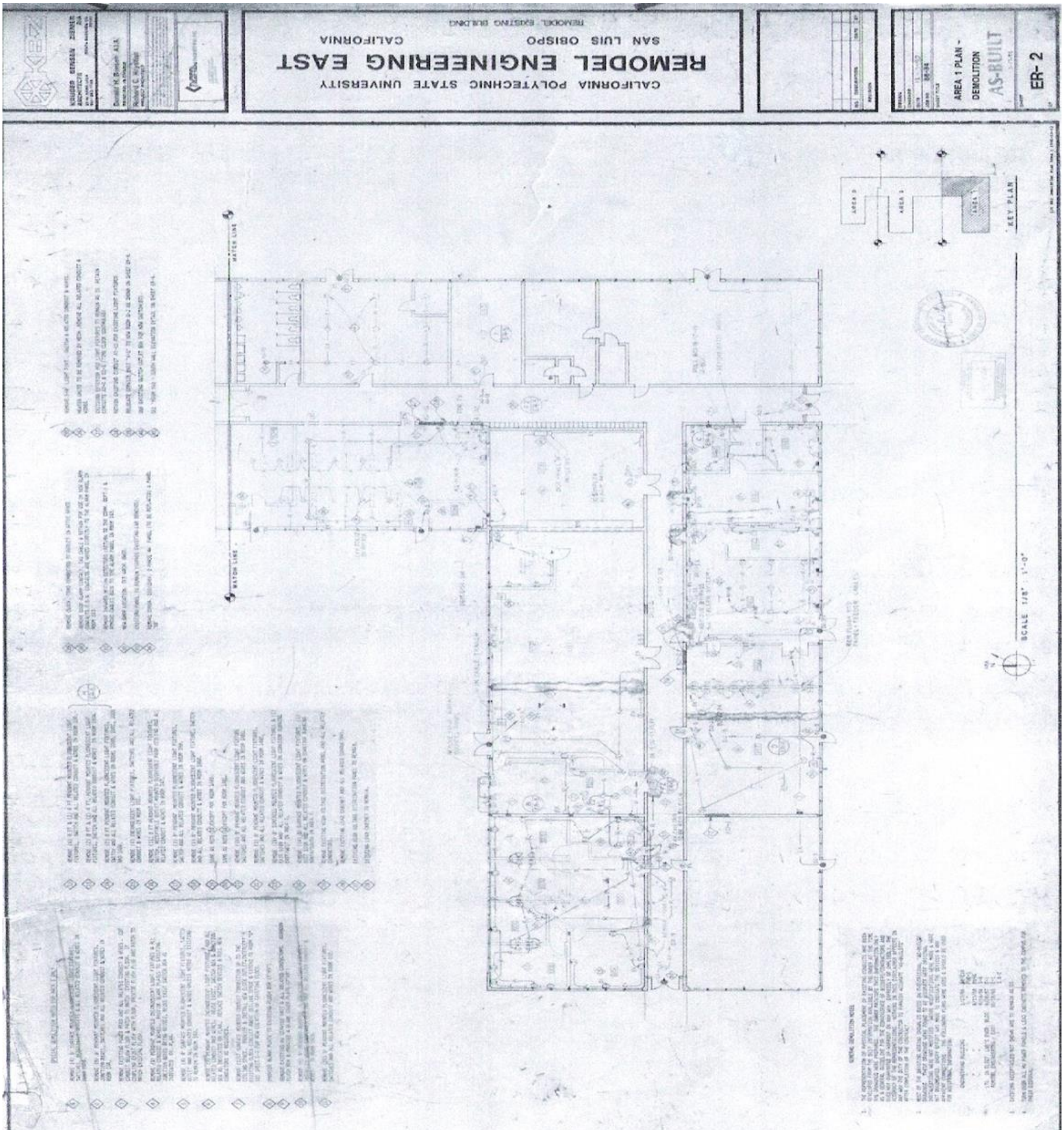

Figure 17. – 1990 Remodel Plans & Interconnections Building 20 South

APPENDIX B. Facility Planning Room Data

TABLE V. Facility Room Data: Building 20

Choose Another Facility

Cal Poly Space Data

Facility:020-0 | Show Non-Assignable | Data in Excel, Includes all Facilities

Facility	Building	Room	College	Dept	Room Type	Area	Level	Stations	FTES	CAD_No
020-0	020-0	0100-00	Engineering	BMGE	UpDiv Teach Lab	1,632	2	16	6.24	0200010000
020-0	020-0	0101-00	Engineering	EE	Spec Instruction	1,238	0	0	0	0200010100
020-0	020-0	0102-00	Engineering	EE	UpDiv Teach Lab	1,427	2	16	6.24	0200010200
020-0	020-0	0104-00	Engineering	EE	UpDiv Teach Lab	913	2	16	6.24	0200010400
020-0	020-0	0105-00	Engineering	EE	Spec Instruction	672	0	0	0	0200010500
020-0	020-0	0106-00	Engineering	EE	Maint Rpr Sp	830	0	0	0	0200010600
020-0	020-0	0106-A0	Engineering	EE	Staff Office	118	0	1	0	020001060A
020-0	020-0	0106-B0	Engineering	EE	Staff Office	148	0	1	0	020001060B
020-0	020-0	0106-C0	Engineering	EE	Staff Office	179	0	1	0	020001060C
020-0	020-0	0106-D0	Engineering	EE	Maint Rpr Sp	104	0	0	0	020001060D
020-0	020-0	0107-00	Engineering	EE	Maint Rpr Sp	240	0	0	0	0200010700
020-0	020-0	0107-A0	Engineering	EE	Maint Rpr Sp	428	0	0	0	020001070A
020-0	020-0	0108-00	Engineering	EE	Tch Lab Serv	340	2	0	0	0200010800
020-0	020-0	0109-00	Engineering	EE	Gen Storage	69	0	0	0	0200010900
020-0	020-0	0110-00	Engineering	EE	Tch Lab Serv	433	2	0	0	0200011000
020-0	020-0	0111-00	Engineering	EE	Spec Instruction	1,131	0	0	0	0200011100
020-0	020-0	0112-00	Engineering	EE	UpDiv Teach Lab	1,023	2	16	6.24	0200011200
020-0	020-0	0113-00	Engineering	EE	UpDiv Teach Lab	1,023	2	16	6.24	0200011300
020-0	020-0	0114-00	Engineering	EE	Tch Lab Serv	468	3	0	0	0200011400
020-0	020-0	0115-00	Engineering	EE	Slf Inst Lab	699	0	16	0	0200011500
020-0	020-0	0116-00	Engineering	EE	UpDiv Teach Lab	1,251	2	16	6.24	0200011600
020-0	020-0	0117-00	Engineering	EE	Tch Lab Serv	562	2	0	0	0200011700
020-0	020-0	0118-00	Engineering	BMGE	Spec Instruction	680	0	0	0	0200011800
020-0	020-0	0118-A0	Engineering	BMGE	Faculty Use	439	0	6	0	020001180A
020-0	020-0	0119-00	Engineering	EE	Spec Inst Sup	334	0	0	0	0200011900
020-0	020-0	0119-A0	Engineering	EE	Spec Inst Sup	87	0	0	0	020001190A
020-0	020-0	0121-00	Engineering	BMGE	Tch Lab Serv	1,223	2	0	0	0200012100
020-0	020-0	0122-00	Administration	AV	Gen Storage	76	0	0	0	0200012200
020-0	020-0	0123-00	Administration	AV	Gen Storage	240	0	0	0	0200012300
020-0	020-0	0124-00	Engineering	BMGE	UpDiv Teach Lab	1,132	2	16	6.24	0200012400
020-0	020-0	0126-00	Engineering	BMGE	Slf Inst Lab	908	0	16	0	0200012600
020-0	020-0	0127-00	Engineering	BMGE	UpDiv Teach Lab	1,045	2	24	9.36	0200012700
020-0	020-0	0127-A0	Engineering	BMGE	Tch Lab Serv	153	2	0	0	020001270A
020-0	020-0	0127-B0	Engineering	BMGE	Tch Lab Serv	172	1	0	0	020001270B
020-0	020-0	0128-00	University	ALL	Lecture	583	0	26	60.58	0200012800
020-0	020-0	0129-00	University	ALL	Lecture	562	0	26	60.58	0200012900
020-0	020-0	0130-00	Engineering	BMGE	Grad Rsrch Lab	1,023	3	8	0	0200013000
020-0	020-0	0131-00	Engineering	EE	UpDiv Teach Lab	1,400	2	24	9.36	0200013100
020-0	020-0	0132-00	Engineering	EE	Tch Lab Serv	1,390	2	0	0	0200013200
020-0	020-0	0133-00	Engineering	EE	Faculty Use	1,597	0	8	0	0200013300
020-0	020-0	0134-00	Engineering	EE	Tch Lab Serv	675	2	0	0	0200013400
020-0	020-0	0135-00	Engineering	EE	Tch Lab Serv	677	2	0	0	0200013500
020-0	020-0	0136-00	Engineering	EE	UpDiv Teach Lab	908	2	16	6.24	0200013600
020-0	020-0	0139-00	University	ACPG	Spec Instruction	562	0	0	0	0200013900
020-0	020-0	0140-00	Engineering	EE	Spec Instruction	790	0	0	0	0200014000
020-0	020-0	0143-00	University	ACPG	Spec Instruction	446	0	0	0	0200014300
020-0	020-0	0144-00	Engineering	EE	Gen Storage	369	0	0	0	0200014400
020-0	020-0	0144-A0	Engineering	EE	Gen Storage	68	0	0	0	020001440A
020-0	020-0	0145-00	Engineering	EE	UpDiv Teach Lab	1,315	2	16	6.24	0200014500
020-0	020-0	0145-A0	Engineering	EE	Tch Lab Serv	65	2	0	0	020001450A
020-0	020-0	0146-00	Engineering	EE	LwDiv Teach Lab	702	1	16	8.32	0200014600
020-0	020-0	0147-00	Engineering	EE	LwDiv Teach Lab	792	1	16	8.32	0200014700
020-0	020-0	0148-00	Engineering	EE	LwDiv Teach Lab	821	1	16	8.32	0200014800

020-0	020-0	0149-00	Engineering	EE	LwDiv Teach Lab	764	1	16	8.32	0200014900
020-0	020-0	0150-00	Engineering	EE	UpDiv Teach Lab	1,391	2	16	6.24	0200015000
020-0	020-B	B910-00				596				000ZB91000

APPENDIX D — ANALYSIS OF SENIOR PROJECT DESIGN

Project Title: Nanogrid Electrical Design and Analysis

Student's Name: Phillip Phung **Student's Signature:**

Advisor's Name: William Ahlgren **Advisor's Initials:** **Date:** 03/20/2015

• 1. Summary of Functional Requirements

The product function simulates the power system abilities of Cal Poly's Building 20, including transformer characteristics through existing LVDS. Also, simulating the campus protection grid enables further testing using simulated fault currents. Overall, analysis of the complete system enables more comprehension when installing a nanogrid within Building 20 to simulate a campus microgrid.

• 2. Primary Constraints

Originally, power faults analysis would lead to the creation of another generation system on campus, but the advisor recommended toning down the project scale's resulting costs, paperwork, and time unavailable. Another issue included what type of simulation program has the ability to implement the campus grid. Power World and ETAP programs both simulate power grids, but not the size of this campus. Professor Algren recommended SKM Power Analysis to plot the complete schematics, but while the previous programs cost nothing, SKM's price range cost thousands. Fortunately, a Cal Poly alumni working at SKM subsided the cost, so the basis of this entire project rotates around SKM Power Analysis.

Other challenges included verifying schematics and data for each of the interconnecting feeders leaving the transformer room. Verification of existing LVDS panels and power cable lines from design schematics and plot plans required Facilities permission and presence, and difficult due to the workload of Facilities.

• 3. Economic

Not much economic impact occurs from simulation, but the overall analysis contributes to Cal Poly's future nanogrid interconnection project in Building 20. Thus, direct state holders include Cal Poly facilities, SKM Systems Analysis, Inc., and my advisor, which directly affect these simulations. Indirectly, the Cal Poly Corporation, students, and campus utilities become affected by implementation of this project after multiple simulations are completed.

Most cost and benefits accrue during the purchase of parts including texts and SKM if unsubsidized

by the company for student projects. SKM choice over ETAP due to the

Information about the campus grid, which entails help from facilities, information using text references labelled in IEEE format near the bottom of this appendix, and SKM Power Analysis institute main parts necessary to accomplishing the task at hand. Total cost projections, which include probable subsidization by SKM, shown below:

Table 6. Cost Table (Actual Highlighted)

	Labor Cost	Parts Cost	Total Labor Time	Total Costs	Estimate Cost Average
Optimistic ($Cost_a$)	~~$1520~~	$0	152 days	~~$1520~~	$4420
Most Likely ($Cost_m$)	$3000	$400	300 days	$3400	
Pessimistic ($Cost_b$)	$6000	$5400	600 days	$11400	

Ignoring labor cost, this project actually used $0 due to subsidization of SKM using help from a Cal Poly alumni. The purpose of this project relates not to earnings, but the analysis of whether construction of future on-site generation systems have adequate protection and interconnection schemas, as only the northern part of Building 20 will be feasible for solar PV distributed generation.

Around May 6th and May 26th, two test iterations occur through simulation of how fault currents cause protection schemas to respond. This does not lead to further costs due to irrelevance of costs incurred by adjusting simulations.

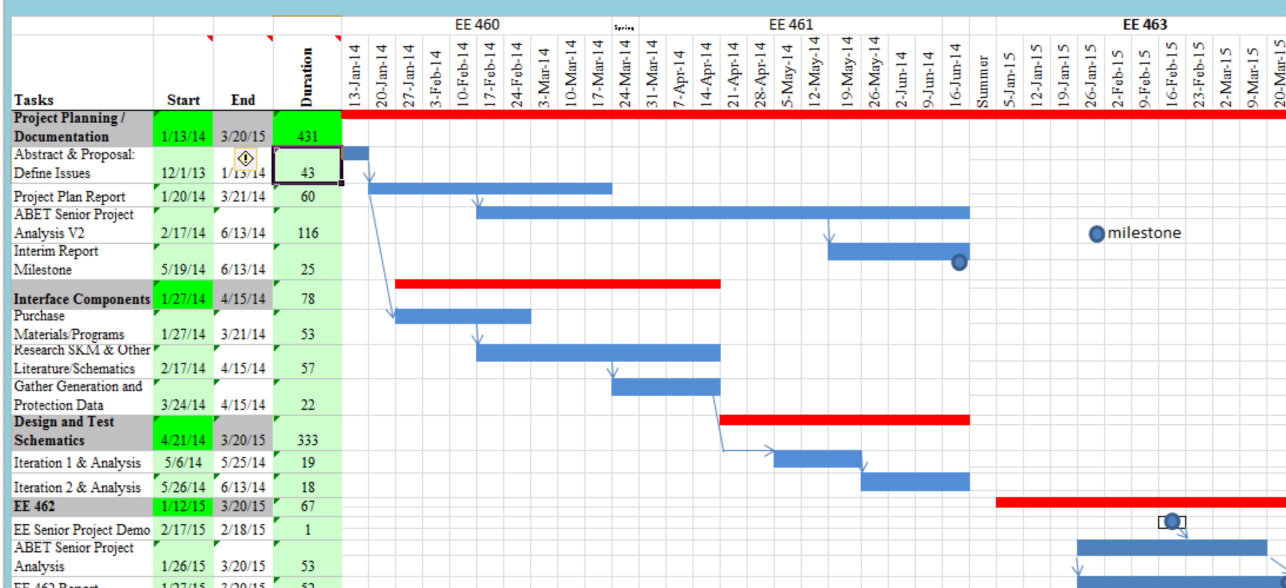

Figure 18. Gnatt Chart of Project Timeline

After the completion of this project, other individuals, senior/graduates, build on by continually analyzing, planning, and developing Cal Poly's possible LVDS nanogrid.

• 4. If manufactured on a commercial basis:

This product results from SKM analysis, and manufactures very little using all components necessary for a fully running campus simulation rather than actually built. Very rarely do power systems get build first and then tested, as the economics accrue unattainable recovery costs for each mistake. This explains why model analysis precedes implementation of a multi-million dollar project according to cost-analysis.

• 5. Environmental

This project uses provided and researched information to create a simulation of power systems on Building 20. No manufacturing is required, so equipment used does not have much environmental impact. However, the aim of the analysis is to produce a distributed generator, such as a PV array, on campus to interconnect to a miniature microgrid, or nanogrid. The aim of this design after multiple simulation and studies, improves power efficiencies and reduces power consumption. The direct result of this ensures Cal Poly's reduction of the ecological footprint of this Earth, while creating better understand of microgrid technology through LVDS.

• 6. Manufacturability

When implementing the transformer room and feeders as one simulated schematic, using previous schematics implemented by Facilities means one does not have to reinvent the wheel. Once again, no manufacturing will be necessary due to the implementation of SKM using Building 20 schemantics/plot plans in order to ensure analysis of power system efficiencies and adding distributed generation.

• 7. Sustainability

Issues involve the SKM program and following analysis seem relatively simple to solve compared to concrete electrical devices because simulated programs result from making fixes for large mistakes. A forgotten simulated transformer does not require more components or laying new foundation, but rather a simple transformer schematic addition. After completion of the campus building design, the SKM schematics improve analysis by simulating multiple fault currents, viewing whether or not power protection works properly.

As power conservation and generation contain important aspects of Cal Poly's campus, another simulation of a generator not yet built on this campus perceives the effects of more localized power generation at relatively not cost whatsoever. Thus, simulation tools prove as powerful methods of determining power usage and faults without spending thousands to literally generate actual faults in the real generation and transmission areas. Yet, the challenge is implementing this SKM technology onto campus, as the alumni connected to Professor Ahlgren will allow future students to use the program for free each year, but implementation on a whole into Building 20's computer systems would cost upwards $1000.

• 8. Ethical

Though analysis of Cal Poly's protection grid through the SKM program does not seem to have unethical effects, the effects exist in part with a larger project overall. Such analysis helps create an on-campus power hub conflict with IEEE Code Ethics #5: to improve the understanding of technology; its appropriate application, and potential consequences. The potential conflicts result with utilities, through building the microgrid on campus, would be avoided in simulation and construction of a nanogrid, or simulated microgrid in Cal Poly's Building 20.

As these products result from simulation upon simulation rather than an actual concrete device, no physical harm results when interacting with the final product. Rather than wasting energy within campus, or working with voltages up to 12kV, analysis of data through simulation alleviates the danger of faults occurred or caused by probing the campus grid. This is directly related to IEEE's Code of Ethics, in which engineers take responsibility of the well-being and safety of the public through their actions.

• 9. Health and Safety

Some of these schematics analyzed needed confirmation that certain panels within LVDS of Building 20 still existed or were presumed removed. Accuracy in the feeder diagram of each existing panel through the transformer room necessitates a field visit of the transformer room, which requires Facility's permission. Not researching the information with Facility present could lead to injury to individual, or property damage of the grid within the LVDS.

• 10. Social and Political

When analyzing a simulation which contributes to power hub analysis, many social and especially political conflicts occur. First off, Cal Poly uses cogeneration systems with natural gas pumped in from PG&E. A power hub built entirely on renewable energy can seamlessly connect on and off the main grid. Cal Poly's not on any grid, but still relies upon PG&E's natural gas deposits.

At the present, building a nanogrid does not affect Cal Poly's position with PG&E, which prevents Cal Poly from disconnecting completely off this utility's grid. Even though a microgrid campus is not feasible presently, Cal Poly students have the ability to study the nanogrid in Building 20 when more simulation provides the location where distribution generation interconnects to the LVDS. The result of this report will increase electrical engineering students of power system's shifting technological paradigm since the last century.

• 11. Development

The most important tool analyzes the schematic of the campus using SKM Power Tools, which necessitates hours upon hours of research including manuals and tutorial analysis. Further readings allow better analysis of how distribution generation affect power systems work, as viewed below:

Literature References

[1] Jaideep Gill, "*Poly Canyon Cogenerational System*", Dept. Elect. Eng., California Polytechnic State University, California 2011.

Report implements generation systems in Poly Canyon, and research enables further analysis using other cogeneration campus systems. Authority comes from Professor William Ahlgren though advising and guiding senior project under power system emphasis. Currently, report on Google Scholars, but not cited presently.

[2] Minesh D Patel, *"Cal Poly Power System Design and Analysis"*, Dept. Elect. Eng., California Polytechnic State University, California 2011.

Senior project report initializes campus grid design simulation with more emphasis on interconnections than power protections, and useful to prevent reinventing extensive campus simulation. Authority gained from reviews with Professor Amhad Nafisi and William Ahlgren, both Cal Poly professors involved in power systems.

[6] Unkown. (2014, Febuary 3) Campus Operations [Online] Available: http://afd.calpoly.edu/sustainability/campusoperations.asp?pid=5.

Website enables resources and figures from Cal Poly Facilities informing reader of basic energy and electrical operations during an annual basis. Authority uses Cal Poly's Administration and Finance Department from main website as facilities subset.