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Electric Utility System Master Plan

October 1992

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MASTER

Introduction

Proper planning for electric utilities is one of the most important considerations for providing adequate and reliable electric service to any facility. At Lawrence Livermore National Laboratory (LLNL), a multidiscipline institution involved in large-scale applied research and development programs, great importance is given to the planning, acquisition, operation, and maintenance of the electric utility system to achieve the mission of the Laboratory.

The goal of this Master Plan is to provide guidelines which will continue to ensure that reliable electrical service will be available to accommodate the growth of the Laboratory and to fulfill all predictable future programmatic needs.

The Master Plan has been organized into the following sections:

- Section 1: General information, LLNL history and background data, and the history and availability of the electric utility supply.
- Section 2: Existing conditions, including an operational description and operating constraints.
- Section 3: Planning analysis, providing historical and predictable future energy requirements, and the rationale for various proposals to resolve present and future problem areas.
- Section 4: Long-range plan, site development, and the proposed improvements and expansions required.
- Section 5: Five-year plan, descriptions, definitions, including facilities required for funded programmatic needs and electric utility system reinforcement requirements as planned and funded by the approved Line Item Electrical Power System Replacements and Upgrades (EPSRU). Additional General Plant Project (GPP) proposals have also been included.

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Abbreviations, Acronyms, and Definitions

CRYO	Cryogenic Substation—115/4.16 kV, 12.5 MVA substation used by the Magnetic Fusion Project.
EDS	Electrical Distribution System—medium-voltage (12 or 13.8 kV) system used to distribute power from incoming utilities to buildings and substations.
EPSRU	Electrical Power System Replacements and Upgrades—line item funding project for rebuilding the distribution system and correcting code violations.
GIS	Gas Insulated Substation—115 kV-rated enclosure of gas insulated switchgear, metal enclosed and insulated with sulfa-hexafluoride (SF ₆) gas.
LGS	Load Grid Switchgear—medium-voltage (13.8 kV) metal-clad switchgear enclosure, including a lineup of circuit breakers, metering, controls, and similar items.
Loop Style Feed	Normal utility distribution system allowing one circuit to enter and then leave a piece of equipment, all the way through to the last piece of equipment, and then loop back to the source voltage supply.
SCADA	Supervisory Control and Data Acquisition—remotely operated and monitored system used to control equipment on the Electric Distribution System.
U-424	Designation of the 115 kV Switchyard immediately south of Building 424.

1. General Information

1.1 Background Information—Livermore Site

1.1.1 General

Lawrence Livermore National Laboratory (LLNL) is operated by the University of California under contract with the U.S. Department of Energy (DOE). Founded as a nuclear weapons design laboratory in 1952, LLNL has diversified into other fields. However, it remains a mission-oriented institution engaged in large-scale applied research programs that require a multidiscipline approach. LLNL is recognized internationally as a broadly based research center.

1.1.2 Location

LLNL, Livermore Site, is located on an 821-acre site at the eastern end of the Livermore Valley in southern Alameda County, California, about 50 miles southeast of San Francisco. Land uses in the surrounding valley are developing urban, residential, light industrial, commercial, and residual agricultural land.

Sandia National Laboratories, Livermore (SNLL), occupies land to the south of LLNL, with a public road (East Avenue) separating the two DOE facilities.

LLNL Livermore and SNLL share facilities such as fire protection, a cafeteria, parking lot, and utilities. The surrounding undeveloped area consists of sparsely settled rangeland; the terrain is covered predominantly with grasses and chaparral. Some residential development has occurred west of the LLNL site.

1.1.3 Physical Description

Climate. The Livermore Valley has two distinct seasons, the rainy season and the dry season.

Precipitation. The rainfall, which normally averages 14 inches a year, occurs primarily between October and May. In the winter rainy season, the hills are bright green and there is an active runoff. Winter temperatures are mild. Frost usually occurs only at night, and temperatures below 20°F are rare.

Spring and fall are also mild with intermittent rain. Freezing is rare, and temperatures range between 60°F and 80°F. Summers are hot and dry with temperatures often reaching 80°F to 100°F. The landscape usually remains green until the rains stop in late April and May.

Prevailing Winds. Throughout the year, the valley is breezy and windless days are rare. Prevailing winds come from the west and southeast. The westerlies provide some relief in the hot summer by extending the moderating influences of the ocean inland.

Topography. Although LLNL Livermore Site is perceived as flat and level, the southeast corner is 100 feet higher than the northwest corner. The gently falling slope across this diagonal is a fairly consistent one and one-half percent (1-1/2%). Three arroyos (water channels that dry up during the summer) intersect the site. Arroyo Seco flows west across the SNLL site south of the office and laboratory area. Arroyo Las Positas originates in the Livermore hills east of LLNL. It crosses Greenville Road and flows westerly into a drainage retention basin near the center of the site. This outlet constitutes the principal pathway for LLNL's surface drainage off site. The third drainage system is along Greenville Road and turns west along the North Buffer Zone, eventually exiting in the northwest corner of LLNL.

Subsurface Features. The LLNL and SNLL laboratories are located in the southeastern portion of the Livermore Valley, a topographic and structural depression cutting east-west across the Central California Diablo Range. Parts of the Livermore Valley are subject to ground motion from large seismic events on the San Andreas, Hayward, and Calaveras Faults, the major known active faults in the San Francisco Bay Area.

1.1.4 Programs

LLNL is engaged in large-scale applied research programs. The mission of LLNL is to be a national resource of scientific, technical, and engineering capability that especially focuses on national security. Major programs performed at the LLNL facility include but are not limited to the following:

- Biotechnology.
- Energy.
- Lasers.
- Nonproliferation/Arms Control/International Security (NAI).
- Technology Transfer.

LLNL is functionally organized within a matrix framework. Each major program has an assigned staff that is supported by various technical disciplines (e.g., engineering, chemistry, computations, and physics). The support staffs are co-located at the program site because of the need to share major experimental facilities. Thus, programs provide enough facility space to house their support personnel.

1.1.5 Population

Approximately 10,900 University, supplemental labor, and Federal Government Staff personnel are presently employed at LLNL Livermore Site and Site 300.

1.1.6 Types of Facilities

Since its formation in 1952, LLNL has acquired many facilities needed to carry out its research mission. Over the years, the gross area of facilities has continued to grow at varying rates and by mid-1992 had reached approximately 5.5 million gross square feet.

The facility uses are:

- Office/drafting uses.
- Light laboratories/shops.
- Heavy laboratories.
- Miscellaneous.

Office/Drafting Uses. Office and drafting areas house about 75 percent of LLNL's staff and are the most densely populated of the four use types.

Light Laboratories/Shops. Light laboratories and shops comprise approximately 20 percent of LLNL facilities. The work environment is typified by smaller equipment and apparatus. Most light laboratories are involved in direct research, and the shops are primarily for research support of the overall laboratory efforts.

Heavy Laboratories. These facilities are usually marked by high-bay construction, overhead cranes, and perhaps shielding. In most cases, heavy laboratory space is directly supported by adjacent light laboratory space.

Miscellaneous. This category includes computer rooms, storage, and office support areas (such as conference rooms, auditoriums, and classrooms).

1.2 History and Availability of Electric Utilities —Livermore Site

The property now occupied by Lawrence Livermore National Laboratory (LLNL) was purchased by the Navy in March 1942 for construction of the Livermore Naval Air Station. The property was then transferred to the Atomic Energy Commission in 1951. The electric service at that time was provided by Pacific Gas and Electric Company (PG&E) over a single 12 kV distribution line.

The normal load at LLNL is presently served at 115 kV from three 115 kV lines. Two lines are supplied from PG&E and the third from Western Area Power Administration (Western). Figure 1 shows the layout of the existing Western and PG&E transmission lines.

PG&E does have one 230 kV line from their Tesla Substation to LLNL. This line is an express feed to the MFE Program and these facilities are not part of this Master Plan.

The PG&E lines originate at the Tesla Substation on Patterson Pass Road, 10 miles east of LLNL. An additional 115 kV electrical service is being supplied by Western over a new 230 kV transmission line from Western's Tracy Substation, located 12 miles northeast of the laboratory. This 230 kV transmission line, which terminates at the 230/115/13.8 kV Western Livermore Substation (WLS), is owned by and was installed by Western.

WLS is located adjacent to the northeast corner of LLNL, and a temporary overhead 115 kV line has been installed to connect WLS with the South Main Substation (U-424) inside the LLNL site. Future plans call for the existing 115 kV overhead line to be reinstalled underground.

Since the installation of the supply line from Western, the PG&E lines have been used as "hot standby." Upon completion of the new gas-insulated 115 kV ring bus on the EPSRU project, the two utility systems, by contract, will be operated in parallel, greatly enhancing the electrical service reliability at LLNL.

Western will also provide 13.8 kV service to approximately one-half of the Laboratory's load from its WLS. It is anticipated that the Western system would be capable of allowing its transformer to remain in operation via an interconnection with PG&E so that any problems on the Western system, such as at the Tracy

Fig. 1. Western and PG&E transmission lines.

Substation or between Tracy and the WLS, would have minimal effect on service to the Laboratory.

1.3 Background Information—Site 300

1.3.1 General

Site 300 is operated by the Lawrence Livermore National Laboratory as a high explosive test facility. Established in 1955 as a remote test facility to support the theoretical and development work at Livermore Site, Site 300 has expanded to include the Advanced Test Accelerator (ATA), Contained Firing Facilities, and the multibeam Fabry-Perot velocimeter.

1.3.2 Location

Site 300 is located on 6,893 acres in both Alameda and San Joaquin Counties about 17 miles southeast of Livermore, California. The surrounding area is sparsely populated, with the majority of land used for livestock ranching. Physics International and Stanford Research Institute (SRI) maintain explosive test facilities near the Site 300 property.

1.3.3 Physical Description

While the climate is similar to Livermore Site, the prevailing winds during the summer and early fall seasons are quite dynamic. The thermal inversion between the easterly San Joaquin Valley and the westerly Livermore Valley creates routine winds exceeding 65 mph. The terrain varies from rolling hills to steep canyons at elevations from 525 to 1070 feet above sea level.

1.3.4 Types of Facilities

A total of 341,427 square feet of space is occupied. Of this, only 4% are considered temporary facilities. All are in relatively good condition, but the General Services Area (GSA) has some overcrowding. The major problems with the infrastructures are the lack of an adequate and reliable water supply and the poor condition of the roads. Both conditions are being remedied. The overhead 12 kV distribution is old and starting to deteriorate. The two substations are adequate to meet the currently forecasted site demands.

1.4 History and Availability of Electric Utilities—Site 300

One substation (T-301) serves the normal three-to-four MW site load. The substation was installed in 1985 and is large enough to carry the site load for the foreseeable future. A second substation (T-525) serves the ATA facility. Built in 1981 for the program, it is now used basically to serve the in-house ATA lighting load. A 12 kV tie-line between the two substations is currently being installed to allow full transfer of load from one substation to the other for both emergency and maintenance situations.

Site 300 is currently served at 115 kV from Pacific Gas and Electric Company's Tesla Substation. The line is tapped at two locations, one at each of the substations (T-301 and T-525).

2. Existing Conditions—Description and Operational Constraints of Existing Electric System

2.1 South Main Substation

The South Main Substation (U-424) is located at the intersection of South Gate Drive and Outer Loop Road inside LLNL Livermore Site. The 115 kV switchyard is north of the Outer Loop Road and south of Building 424. The building houses two 13.8 kV switchgear assemblies, the 115 kV controls, and the metering for both incoming power and feeder circuits to the area substations on the site. (See Figure 2).

The substation area is congested and the configuration and installation of the 115 kV bus places limitations on maintenance and restricts flexibility of operation. To maintain or remove some of the existing equipment, it is necessary that portions of the substation be de-energized.

The 115 kV switchyard at U-424 contains a 115 kV bus network which provides the means for connecting to either 115 kV transmission line through motor-operated switches. The station presently contains 115 kV switches, including one that provides service to a remote 115/4.16 kV, 12.5/16.625 MVA substation located 400 feet northeast of U-424 and serves the Cryogenic (Cryo) Plant.

The two motor-operated line-disconnect switches cannot both be operated in the closed position for an extended period of time, since the station is not presently designed for parallel operation (See Figure 3).

If both lines are energized, load can be transferred without an interruption by closing the alternate switch and opening the preferred switch. The switches are also capable of de-energizing the normal 115 kV line back to the Tesla Substation or WLS.

Additional equipment located in the switchyard includes 115 kV metering, area lighting, and circuit breaker control relays in addition to conduit, cable, and other related electrical equipment required for operation of the substation electrical system. A 40 kW standby generator supplies backup power to the station service on loss of total power.

Transformer T-900 was installed in 1985, and the T-200 transformer went on-line in mid-1989.

An underrated 115 kV SF₆ circuit switcher protects T-900, while a properly rated SF₆ circuit breaker protects T-200.

Located at the north side of U-424 is Building 424, which houses two 13.8 kV switchgear assemblies equipped with vacuum-type circuit breakers. These switchgear assemblies are identified as T-200 and T-900, and they connect to the associated 115/13.8 kV 60/80/100 MVA transformer via bus ducts.

The function of the T-200 and T-900 transformers is to reduce the incoming voltage of the electric power from the 115 kV transmission lines to the 13.8 kV level for distribution to the various load centers on the site. These transformers are equipped with automatic load tap changers which operate to maintain the 13.8 kV output voltage at a constant level as the load on the site varies. Each transformer is capable of delivering a maximum load of 100 MVA.

Both 13.8 kV switchgear assemblies are similar in construction in that they are equipped with two separate main buses. Each bus is served by a 3000 A main circuit breaker which is connected to a corresponding 115/13.8 kV transformer. Each bus in the T-200 switchgear is also connected to a corresponding bus in the T-900 switchgear via a 2000 A tie feeder. The T-200 switchgear assembly contains thirteen 1200 A feeder breakers and space for four additional 1200 A feeder breakers. The T-900 switchgear assembly is equipped with nine 1200 A feeder breakers. Two feeder positions are being used to feed the power factor correction equipment.

2.2 The 13.8 kV Distribution on Site

Electric power is distributed on the site from the U-424 to the area substations by a 13.8 kV resistance-grounded wye system. The majority of this power is delivered through underground conduits, with a small portion on overhead poles.

Figure 2 shows the layout of the existing 13.8 kV electrical distribution system on site.

Fig. 2. Existing electrical system.

Fig. 3. U-424 substation single-line diagram.

Each circuit of the existing underground electrical system between U-424 and the area substations consists, in general, of three 500 KCM cables installed in 4-inch conduits of transite or PVC pipe encased in concrete. In general, these conduits are located on the north and west side of roadways and buried approximately two feet below the surface.

Most existing cables are inadequate in size for carrying the forecasted loads. The size of conduits does not allow for the installation of additional cables or for replacing the existing cables with cables of sufficient size to supply the projected loads. The size of some of the existing manholes is also inadequate to permit the installation of additional cables. Some existing manholes do not have the space to meet the code requirements for bending and pulling the cables or the physical area to accommodate larger cables.

Some of the existing conductors making up the electrical distribution system have been installed over the past 20 years. Small segments, mostly in the northeast and southeast areas, are served from conductors installed on overhead poles. Much of both of these systems are no longer adequate to meet the load growth expected beyond the next five years.

Six fused area substations are presently located on the site. The locations of these are no longer at the load centers. They are supplied by a single circuit from the power source located at the U-424. This configuration does not provide for an alternate source of power for the stations in case of a cable failure.

The purpose of these area substations was to provide voltage regulation and switching control for the feeders which serve the building unit substations. Five of these area stations have fuses for circuit protection. This equipment is obsolete and cannot be depended upon to provide adequate service. The existing fuses do not provide adequate ground fault protection, nor do they have the capacity for proper coordination with the 13.8 kV fuses located at the building unit substations or the relays at Building 424. The sixth area substation contains only switches, no fuses.

When the power distribution system at the laboratory was first developed, it was designed as a loop system which served the area substations. A loop system is comprised of two feeders of equal current carrying capability. Each feeder is able to carry the full assigned load, but is normally limited to 50% of its rated capacity. The open loop system will provide redundant service to each area substation which permits required maintenance and service to be performed with minimum or no downtime. The initial loop system concept has been compromised over the years by the addition of new loads. Two options are possible to resolve this condition: the existing loads must be redistributed to other feeders, thereby reducing the feeder load to the 50% criterion, or new cable must be installed to provide added capacity.

2.3 The 12 kV System

The initial on-site distribution of power on the site was from a PG&E overhead system operated at 12 kV. Over the years, almost all of this original system has been replaced. When the decision was made to replace the 12 kV distribution system with a 13.8 kV system, some of the transformers which reduced the 12 kV primary voltage to the 480 volts used within the buildings had just been installed.

To eliminate the need of replacing these transformers, it was decided to install autotransformers to reduce the revised site standard voltage from 13.8 kV to 12 kV. With such an arrangement, it was possible to avoid early replacement of some 35 transformers. Various General Plant Project (GPP) and Utility Restoration (UR) projects have removed two of the three autotransformers, replaced the building transformers, and changed over the surrounding area to 13.8 kV. Only one autotransformer, at substation No. 5, remains and is scheduled for removal in FY94.

3. Planning Analysis

3.1 Rationale for the Master Plan

The rationale for the electric utility system master plan is based on achieving the service reliability required by DOE 6430.1A. Adequate system capacity, operating flexibility, and maintainability must be considered while providing for all forecasted loads. Also included are the long-term contractual arrangements with the bulk power suppliers, Pacific Gas & Electric (PG&E) and Western Area Power Administration (Western), to supply the forecasted loads and to operate their systems in parallel at U-424. The historical forecasted loads are shown in Tables 1 through 6, and Figures 5 through 8.

The goal of the planning rationale will be accomplished in two phases. These consist of a short-term (five-year) plan and a long-range (five- to 20-year) plan.

The short-term, five-year plan will install 115 kV facilities, allowing both bulk power suppliers to operate their systems in parallel at U-424. This will eliminate power outages to LLNL created by outages to either of their lines. Six new relay-activated circuit breaker switchgear installations, with feeds from both Western Livermore Substation (WLS) and U-424, will be installed as shown in Figure 4. A new duct bank is also included for the express feeders to these new switchgear installations. The remaining 12 kV distribution will be converted to the standard 13.8 kV distribution voltage. The more serious code violations from the 1989 Kaiser Engineering "High Voltage Power Distribution System" report will be corrected.

The long-term (five- to 20-year plan) will achieve the following: (1) modify existing and install new distribution feeders to allow for "loop style" connections; (2) add additional 115/13.8 kV substation capacity; (3) reduce system fault duty; (4) convert the remaining overhead distribution to underground lines; and (5) upgrade the SCADA system to better control the distribution system.

3.2 The Five-Year Plan Includes the Following:

3.2.1 SF₆ Gas-Insulated Substation (GIS)

Replace the air-insulated 115 kV substation bus at Building 424 with a GIS in a ring bus configuration. This will allow both serving utilities to operate in parallel, which will ensure that if either supply were lost, there would be no interruption of service to LLNL.

3.2.2 Load Grid Switchgears

Replace six area distribution centers with six Load Grid Switchgears (LGS) containing modern vacuum circuit breakers and associated protective relay devices. Each LGS assembly contains eight feeder outlets. These 48 feeder outlets will replace 15 existing feeder outlets at U-424. Each LGS will be supplied by express feeders from two locations: the WLS and U-424. Of the eight feeders at each LGS, four will be served from each substation (WLS and U-424). If either substation should fail, a "high speed transfer scheme" at each LGS will automatically transfer the load to the other substation. All interconnecting facilities will be sized to satisfactorily accommodate this transfer.

SCADA facilities will be installed on all LGS incoming and outgoing feeders. The master control room will be located in B-517 with future backup provided in U-424.

3.2.3 Underground Duct Bank and Manhole System

Each circuit of the existing underground electric system between the main substation and the area substations, in general, consists of three 500 KCM cables installed in 4-inch conduits of transite pipe or PVC pipe encased in concrete. In general, these conduits are located on the north and west side of roadways and buried approximately two feet below the surface. No empty ducts remain, and each contains the

Fig. 4. The 13.8 kV underground duct bank system layout.

maximum number of conductors permitted by code. This constraint on size and fill does not allow for the installation of additional cables or for replacing the existing cables with cables large enough to supply the projected loads.

The sizes of most of the existing manholes are inadequate to permit the installation of additional cables. Most manholes do not have the space necessary to meet code requirements for bending and pulling the cables or the physical area to accommodate cables of the size required to supply the forecasted load.

It is planned that a new underground duct bank and manhole system be installed from WLS and U-424 to the new LGSs for installation of the associated express feeders. The ducts in the multiduct bank system will be 6-inch and the express feeders will generally be 750 KCM. Each LGS will be sized to serve an ultimate load of 25 MVA. The existing underground duct bank and manhole system will be retained wherever possible for use with the 13.8 kV distribution systems which extend from the LGS assemblies to the unit substations or other load centers. The cables in the distribution system will be sized as required.

Figure 4 shows the route for the express duct bank.

3.2.4 Electrical Code Corrections

A comprehensive electrical survey of the medium voltage distribution has been completed by a group of qualified experts in medium/high voltage systems. The survey results revealed numerous safety code violations and good practice items that should be corrected. The most serious code violations have been corrected, and the balance are in the process of being completed.

3.2.5 Replacement of Low Voltage Feeders and Panelboards

The previously mentioned electrical survey also showed that of the LLNL buildings which are 25 years old or older, 21 had low voltage feeders requiring replacement due to cable deterioration. Increased fault duty has correspondingly increased personnel exposure and, in the case of failure of the feeder, may contribute dramatically to increased programmatic downtime. These feeders must be replaced.

3.2.6 Unsafe Panelboards

Of 535 panelboards surveyed, 251 require replacement because they are considered unsafe. Most fail to meet the criteria for their ability to interrupt the available short circuit current. If required to operate during a fault, the circuit breaker and panelboards could fail catastrophically requiring considerable time to repair and increased programmatic downtime.

3.2.7 The 12 kV and Overhead Conversion

The 12 kV distribution system on the west side of LLNL has reached the end of its life cycle. Most of the system has been converted to the LLNL standard voltage of 13.8 kV. To eliminate this radially fed 12 kV system, this project will convert the 12 kV to 13.8 kV and relocate the 12 kV overhead distribution in underground lines, allowing an alternate distribution feeder to be installed to feed these critical programmatic loads.

3.3 The Long-Term (Five- to 20-Year) Plan Includes the Following:

3.3.1 The 13.8 kV Duct Bank and Distribution System

Replace and upgrade the 13.8 kV duct bank and distribution system to provide at least a loop style service to all existing building unit substations. Additional SCADA alarms, control metering, and fault monitoring systems and locations will be installed as necessary.

3.3.2 The 115 kV Substation and Transmission Loop

When the LLNL load exceeds the firm substation capacity of 100 MVA, an additional 115/13.8 kV substation transformer and associated transmission loop will be constructed. Additionally, the existing temporary overhead 115 kV from WLS to U-424 will be placed underground.

3.3.3 Upgrades to SCADA System

Provide additions and upgrades to the SCADA system allowing for adequate control and monitoring of all distribution class equipment at LLNL.

3.3.4 Reduce System Fault Duty

Since the substation transformers at U-424 were initially installed, the fault current capability of the utility supply has allowed the fault duty to increase to 32,000 A. Electrical equipment manufacturers normally supply material with a maximum 25,000 A capacity, and some supply equipment to 40,000 A, but at a significantly increased price.

To have properly rated equipment, 40,000 A-rated material must be installed. The alternative is to reduce the capacity to below the 25,000 A limit.

Industry-accepted practice is to install current-limiting reactors in the high voltage side of the substation transformers.

3.3.5 Overhead Conversion

Convert the northeast, northwest, and southeast overhead 13.8 kV distribution systems to underground. This will dramatically improve the service reliability in these areas of the lab.

3.3.6 Upgrade LGS Express Feeders

Install new duct bank from U-424 to LGS-15 and add the third 750 KCM cable per phase on all LGS express feeders to allow all future loads to be carried while maintaining voltage within LLNL approved standards.

3.4 Future Energy Requirements

The future demand (peak load) and energy use requirements are projected using three different scenarios. The historical load and energy usage is used as the base line for all three projected scenarios.

Table 1 and Figure 5 show the historical demands for the Livermore Site only. The Site 300 historical load is shown on Table 3. The Sandia historical loads are included in the Livermore Site data and are shown on Table 4. The Sandia forecasted load is included in Scenario #2.

The three possible scenarios used for load projections are shown in Table 2 and are described in the following summaries:

Scenario #1—This projected scenario represents the most likely case and is based on historical load growth. These values are to be used for power purchase contracts, as well as substation and transmission facilities planning.

Scenario #2—In addition to Scenario #1, this case includes Sandia projected growth plus the new, funded LLNL facilities. These values are to be used for capital investment planning for the sitewide distribution system. See Table 5.

Scenario #3—This projection includes Scenario #2 plus all proposed new facilities and uncertain programmatic experimental loads. Data is presented to show a "very optimistic" view but is not being used for budgeting electrical projects. See Table 6.

Table 1. Livermore Site—main meter.

Historical consumption									
Fiscal year	Main EDS max. demand (MW)	Main EDS total energy (MWh)	Main EDS increased demand (MW)	Main EDS increased energy (MWh)	Fiscal year	Main EDS max. demand (MW)	Main EDS total energy (MWh)	Main EDS increased demand (MW)	Main EDS increased energy (MWh)
1970	26.7	159,811			1982	42.1	227,916	(-0.8)	7,814
1971	28.2	167,100	1.5	7,289	1983	46.7	245,403	4.6	17,487
1972	29.2	177,800	1.0	10,700	1984	48.8	278,148	2.1	32,745
1973	33.9	177,100	4.7	(-700)	1985	52.0	294,506	3.2	16,358
1974	30.9	178,983	(-3.0)	1,883	1986	52.4	323,393	0.5	28,887
1975	33.1	180,866	2.2	1,883	1987	56.8	329,086	4.4	5,693
1976	38.5	193,635	5.4	12,768	1988	59.3	344,940	2.5	15,855
1977	36.5	201,100	(-2.0)	7,465	1989	61.1	355,225	1.8	10,285
1978	40.0	216,476	3.5	15,376	1990	62.8	359,903	1.8	4,677
1979	40.6	226,554	0.6	10,078	1991	61.5	359,275	(-1.4)	(-3,628)
1980	41.2	221,482	0.6	(-5,072)	1992	61.3	364,716	(-0.2)	8,441
1981	42.8	220,102	1.7	(-1,380)	1993 Average:			1.6	9,459

Fig. 5. Livermore Site—main meter.

Fig. 6. Livermore Site—main meter.

Fig. 7. Livermore Site—main meter.

Fig. 8. Site 300 historical load pattern.

Table 2. Annual energy and demand forecast summary.

Fiscal year	Scenario #1 Most likely case		Scenario #2 High but possible		Scenario #3 Very optimistic	
	Maximum demand MW	Total energy MWh	Maximum demand MW	Total energy MWh	Maximum demand MW	Total energy MWh
1992*	61.3	364,716	61.3	364,716	61.3	364,716
1993	62.9	374,175	67.6	392,085	67.6	392,085
1994	64.4	383,633	73.3	414,246	79.5	432,253
1995	66.0	393,092	76.0	430,893	87.0	473,659
1996	67.6	402,551	77.7	440,852	91.1	490,910
1997	69.2	412,010	79.7	452,511	93.5	504,124
1998	70.7	421,468	81.4	462,669	98.2	532,499
1999	72.3	430,927	83.2	474,828	100.7	546,582
2000	73.9	440,386	84.9	482,987	102.4	556,741
2001	75.5	449,845	86.6	493,146	104.2	566,900
2002	77.0	459,303	88.3	503,304	105.9	577,058
2003	78.6	468,762	90.1	513,463	107.6	587,217
2004	80.2	478,221	91.9	523,622	109.4	597,376
2005	81.8	487,680	93.5	533,781	111.1	607,534
2006	83.3	497,138	95.3	543,939	112.9	617,693
2007	84.9	506,597	97.0	554,098	114.5	627,852
2008	86.5	516,056	98.7	564,257	116.3	638,011

*Actual maximum demand

Table 3. Lawrence Livermore National Laboratory—Site 300
annual energy and demand forecast summary.

Fiscal year	Maximum demand MW	Total energy MWh	Delta MW	Increase MWh
1975*	2,151	27,906		
1976*	2,130	32,096	0.8	4,190
1977*	2,186	35,400	0.8	3,304
1978*	2,188	39,780	0.5	4,380
1979*	2,396	38,200	-0.6	(-1,580)
1980*	2,190			
1981*	2,362	36,593	-0.3	(-1,607)
1982*	2,538	39,178	0.8	2,585
1983**		50,400	2.1	11,223
1984	2,882	51,200	0.2	800
1985		54,200	0.5	3,000
1986				
1987		54,780	0.1	500
1988		56,900	0.5	2,200
1989		57,600	0.1	700
1990		58,300	0.2	700
1991		59,000	0.1	700
1992				
1993•		59,700	0.2	700
1994•		60,400	0.1	700
1995•		61,100	0.2	700
1996•		61,800	0.2	700
1997•		62,500	0.1	700
1998•				
1999•		63,200	0.2	700
2000•		63,900	0.1	700
2001•		64,600	0.2	700
2002•		65,300	0.1	700
2003•		66,000	0.2	700
2004•				
2005•		66,700	0.1	700
2006•		67,400	0.2	700
2007•				

*Estimated demand data used for FY75 through FY82

**No data available for FY83

•Averages were calculated for FY93 through FY07 using FY84–91 data

Table 4. Sandia National Laboratory, Livermore Site—main meter. Annual forecasted power requirements—1992–2012.

Fiscal year	Maximum demand MW	Total energy MWh	Delta MW	Increase MWh
1986	5.3	27,906		
1987	6.1	32,096	0.8	4,190
1988	6.9	35,400	0.8	3,304
1989	7.4	39,780	0.5	4,380
1990	6.8	38,200	-0.6	(-1,580)
1991	6.5	36,593	-0.3	(-1,607)
1992	7.3	39,178	0.8	2,585
1993	9.4	50,400	2.1	11,223
1994	9.6	51,200	0.2	800
1995	10.1	54,200	0.5	3,000
1996	10.2	54,780	0.1	500
1997	10.7	56,900	0.5	2,200
1998	10.8	57,600	0.1	700
1999	11.0	58,300	0.2	700
2000	11.1	59,000	0.1	700
2001	11.3	59,700	0.2	700
2002	11.4	60,400	0.1	700
2003	11.6	61,100	0.2	700
2004	11.8	61,800	0.2	700
2005	11.9	62,500	0.1	700
2006	12.1	63,200	0.2	700
2007	12.2	63,900	0.1	700
2008	12.4	64,600	0.2	700
2009	12.5	65,300	0.1	700
2010	12.7	66,000	0.2	700
2011	12.8	66,700	0.1	700
2012	13.0	67,400	0.2	700

Table 5. Estimated power requirements for possible future experimental loads.

Activ- ation date	Fiscal year	Project title	Description	Funded/ proposed	Building (see legend)	Gross square footage (kft ²)	kWh/ gsf/ month	W/gsf/ month	MWh/ month	Annual energy usage (MWh)	Maximum demand (kW)
3/93	1993	NTTC	Nuclear Test Technical Complex	F	LL/O	172	6	15	1,114.6	13,374.7	2,580.0
10/93	1994	SAB	Security Administration Building	F	O	36	2	6	77.8	933.1	216.0
3/94	1994	DPRF	Defense Program	F	LL/O	194	7	17	1,424.7	17,098.8	3,298.0
10/93	1994	VISTA	Verification Intelligence Special Technical Assessment Center	F	LL/O	47	4	10	201.7	2,420.9	467.0
10/94	1995	AERF	Atmospheric Emergency Response Facility	F	O/Comp	40	9	15	349.1	4,188.7	606.0
10/96	1997	EPRF	Environmental/Physics Research Facility	P	LL/O	35	4	10	151.2	1,814.4	350.0
10/96	1997	DPLSF	Defense Programs Laser Support Facility	P	LL/O	90	3	7	272.2	3,265.9	630.0
10/96	1997	ESHF	Environmental Safety and Health Facility	P	LL/O	30	4	10	129.6	1,555.2	300.0
10/97	1998	GRF	Genomics Research Facility	P	LL/O	41	5	12	212.5	2,550.5	492.0
10/97	1998	LBC	Laboratory Business Center	P	O	120	2	6	259.2	3,110.4	720.0
3/98	1998	DWTF	Decontamination and Waste Treatment Facility	P	ML	96	11	19	1,046.2	12,555.0	1,816.4

Legend

Building type: Office (O) Light laboratory (LL)
Medium laboratory (ML) Computer facility (Comp)

Table 6. Estimated increased power requirements to accommodate possible future experimental loads.

Experiment	Description	Fiscal year	Increased demand MW	Increased energy MWh
NPBSE	Nuclear Particle Beam Space Experiment	1994	3.2	9,335
TMX	Intense Neutron Source Facility	1994	3.0	8,672
INTER	Superconducting Magnet Test Facility	1995	3.0	17,345
MCTF	Model Coil Test Facility	1995	0.8	2,334
STE	Steady State Super Conducting Tokomak Experiment	1996	2.5	7,293
			12.5	44,979

4. Long-Range Plan

4.1 Future Site Development

This Master Plan is based on a long-range planning period from 1993 to 2013. The most recent information on expansion and growth at LLNL is contained in the 1993 Site Development Plan. According to that document, long-range (FY 2010) development is expected within the LLNL site along the newly constructed West Perimeter Road.

Three major areas identified for interior infill growth are as follows: (1) the Northeast Quadrant area between North Inner Loop and North Outer Loop Roads; (2) the Southeast Quadrant area bounded by Avenue K and South Outer Loop Road; and (3) the area west of Avenue A and north of Third Street. Each of these areas is shown on Figure 9.

During the planning period, population and building area are expected to increase moderately. The types of development in newly developed areas are expected to be similar to land uses in existing developed areas. These areas, which total approximately 38 acres, are expected to be filled in with facilities to a density comparable with existing developed areas. In addition to interior infill, a number of areas within the site have been identified for redevelopment.

The total potential expansion area for the long-range plan is 38 acres. A maximum of 45% of any open space may be considered available for the location of new facilities.

This corresponds to 750,000 square feet of potential building area. The current LLNL site area is 821 acres. Figure 10 shows future (long-range) expansion and redevelopment areas, and Table 7 shows major construction projects proposed for the next five years through FY98.

4.2 Physical Improvements and Expansions Required

The physical improvements, expansions, demolition, and replacement of the electric utility

system will improve the appearance of the site in the long term since most of the work will be placed underground or will replace existing equipment with new equipment at the approximate same general location and will be screened by landscaping as necessary. In the short term, there will be some unavoidable disruption for project construction and staging. All projects will be coordinated through the LLNL siting process.

It will not be necessary to expand the 115 kV switchyard¹ at the South Main Substation because a gas insulated ring bus substation (GIS) will be installed. The GIS requires less ground space than the existing air insulated bus system. A decorative wall around the South Main Substation will provide additional security as well as improve the overall appearance of the area.

The load grid switchgear (LGS) assemblies will consist of outdoor metal-clad switchgear installed near the loads. This minimizes expenditure, maximizes efficiency, and improves reliability.

A temporary 115 kV tie line has been installed on wooden poles between the WLS and U-424 substations. The pole locations have been carefully selected to avoid interference with existing trees and preserve the appearance of the site. This line will be tapped to feed Cryo. Future plans call for this line to be reinstalled underground.

Several additional pad mounted sectionalizing switches will be installed throughout the site. Their installation will be in carefully selected locations.

The remainder of the electric system improvements and expansion will be underground or within buildings.

It is planned to replace the existing overhead pole lines in the northeast, northwest, and southeast corners of the site so that the entire site electric system will be underground. This will minimize the number of outages created by acts of nature (birds, lightning, wind, and similar items).

Fig. 9. Existing land use.

Land use legend

Construction projects

P# Proposed projects

R&D

- Institutional
- Redevelopment land
- Vacant land
- Major circulation
- Easements
- Security buffer

0 600 1200
Scale (feet)

0 200 400
Scale (meters)

Fig. 10. Master plan map.

Table 7. Proposed projects from the LLNL Site Development Plan.

See Appen. B	Project	Fiscal \$M year TEC	See Appen. B	Project	Fiscal \$M year TEC
	<i>Budgeted construction</i>			<i>Civil maintenance—sitewide</i>	97 5.0
	Site 300 facilities revitalization project	90 22.1		VHS unclassified data communication	97 10.0
	Electrical power rep/upgrade I	91 31.0		VHS classified data communication	97 25.0
P1	Defense Programs Research Facility (DPRF)	91 72.6	P20	Central cafeteria and conference center	97 6.5
P2	Decontam./Waste Treatment Facility (DWTf) (Includes Mixed Waste Mgmt. Facility [MWMF])	91 74.0	P21	South cafeteria	97 5.5
	Fiber optics comm. backbone	91 4.6	P22	B-123 gen. upgrade (conf. center upgrade)	97 5.2
	Infrastructure modernization	92 13.8	P23	LLIX admin housing	97 3.2
	Sanitary sewer system rehabilitation	92 13.5	P24	Public Affairs center	97 6.0
	Energy conservation retrofits	93 12.5		Elec. power syst. replacement/upgrade II	97 40.0
	Tank upgrades project	93 17.6	P25	Plutonium facility upgrade	97 27.3
P3	Atmospheric Emerg. Resp. Facility (AERF)	93 11.3	P26	Liv. Center for Adv. Manuf. and Productivity	97 70.0
	<i>Proposed construction</i>		P27	Nano scale mat. facility	97 10.1
	Chlorofluorocarbon (CFC) Chiller Conversion	95 16.0	P28	Replace/refurbish Hazard Control Facility	97 14.0
P4	Chemistry bldg. decon. and demo. (B-222)	95 16.2	P29	B231 Upgrade	97 10.5
	Protection of real prop. Roof replacements	95 23.3	P30	B131 general and environmental upgrade	97 15.0
	Road reconstruction	95 5.7	P31	B251 ventilation/seismic/safety upgrade	98 41.4
	Building drains inspection project	95 10.8	P32	Library facility	98 1.9
	Waste accumulation areas	96 6.0		Backlog reduction—roofing	98 19.0
P5	Environ., Safety & Health Facility (ES&H)	96 34.5		Projected utility projects	98 60.8
	Energy Program office building	96 14.0		<i>GB-02 Inertial Confinement Fusion</i>	
	Addition to B543	96 10.0	P33	Defense Programs laser support facility (ICF user/support facility)	96 36.7
	Plasma Physics research facility (Atomic Physics research facility)	96 47.7		<i>Expense projects</i>	
	Evacuation voice alarm	96 13.0		National Ignition Facility pre-const. activities (Nova Upgrade pre-construction activities)	95 40.0
P6	Lab business center	96 36.0	P34	National Ignition Facility (Nova Upgrade)	96 500.0
P7	NW LCW station	96 5.9		<i>GC-01 Arms Control and Nonproliferations</i>	
P8	B191 hazardous firing	96 21.0	P35	Verif., Int'l Security, & Tech. Anal. (VISTA) Ctr.	95 21.7
P9	Earth Science building	96 32.0		Nonproliferation Annex (NPA)	97 9.7
P10	Replace offices, B213, B319, T2175, T2177	96 13.0		(Treaty Verification Center [TVC])	
P11	Technology Transfer complex	96 90.0		<i>Biomedical research</i>	
P12	B212 replace lab	96 63.5		<i>KP-02 biological environment research</i>	
P13	Block 220 C&MS refurbishment	96 6.7	P36	Genomics research laboratory	95 20.5
P14	B151 effluent systems upgrade	97 15.0		Office admin/human resources mgt.	
P15	Hazards Control fire science facility	97 5.0		<i>WB in-house energy management</i>	
P16	B151 plan and seismic upgrade	97 18.0		In-house energy management	94 18.5
	Upgrade smoke detection	97 5.5		<i>Site 300 experimental test site information</i>	
P17	B321 general and environmental upgrade	97 20.0		Contained firing facility	94 36.9
	Fire safety training facility	97 5.1		Perm. explosive waste storage facility	95 1.6
P18	B141 general upgrade	97 5.1		Site 300 wastewater treatment facility	95 11.0
	Backlog reduction—flooring	97 12.0		Fire station and medical facility	95 3.8
P19	B551 W addition for TID	97 8.0		Flash x-ray upgrade II	97 27.8
	Building electrical systems code upgrade	97 29.4		Site facilities revitalization II	97 28.1
	Backlog reduction—painting	97 9.0		HE machining facility	98 16.7
				(See separate Site 300 development plan)	

4.3 Environmental and Safety Adjustments

4.3.1 Environmental Assessment

An Environmental Assessment (EA) has been completed by LLNL, and a Finding of No Significant Impact (FONSI) has been issued for the proposed projects.

Short-term environmental impacts are likely to occur as a result of on-site construction activities. These impacts include dust (evacuation and replacement of soils), noise (heavy equipment operations and general construction activities), disposal of construction and demolition debris, and traffic disruptions near construction areas. Subsequent operations within the electrical distribution system will remain essentially unchanged.

The physical locations of the 115 kV transmission lines, LGS switchgear, and 13.8 kV underground distribution system have been coordinated with existing buildings, roads, and equipment and will be consistent with future plant planning as described in the LLNL Site Development Plan.

No environmental impacts, except those resulting from normal construction activities will occur.

Project-specific activities will include the following:

- Soil sampling prior to excavation.
- Appropriate disposal of soil samples and excavation.

- Testing and safe disposal of removed equipment, including insulating oil.
- Compliance with the Bay Area Air Quality Management District reporting requirements if asbestos is encountered in any of the areas where demolition is to be performed.

Asbestos is not known to exist in any areas planned in this project.

4.3.2 Safety Assessment

A safety assessment for each project will be prepared, or at least an exemption will be sought. The design, construction, and operation of the facilities will comply with DOE, federal, and state regulations and other application codes and standards pertaining to health, safety, and fire protection.

All electric construction will be performed in strict compliance with and conformance to DOE orders, Federal OSHA, California OSHA, National Electrical Code, National Electrical Safety Code, California Public Utilities Commission General Orders GO-95 and GO-128, and LLNL Facilities Standards.

Deteriorated equipment replacement and code compliance will result in a safer, as well as a more reliable system for the operating personnel and users. Seismic design shall be in accordance with LLNL and industry standards.

5. Five-Year Plan Projects

List of Projects (Summary)

Project	Description	Scheduled Completion	Estimated Cost (\$K)
5.1	115 kV South Main Substation (U-424) Replace air insulated switchgear with SF ₆ gas insulated switchgear.	FY94	\$ 5,200
5.2	Load Grid Switchgear (LGS) assembly additions Add five assemblies with vacuum breakers to replace six area switching stations with fuse protection.	FY95	\$16,500
5.3	13.8 kV duct bank and manhole distribution system Add duct bank from U-424 and WLS to each LGS.	FY95	(included with 5.2)
5.4	13.8 kV express feeders—Phase 1 Add 750 KCM copper cable to electrically connect WLS to LGS assemblies.	FY95	(included with 5.2)
5.5	13.8 kV express feeders—Phase 2 Add 750 KCM copper cable to electrically connect U-424 to LGS assemblies.	FY95	(included with 5.2)
5.6	Electrical code improvements Eliminate code violations in the medium- and high-voltage electrical system.	FY95	\$ 4,400
5.7	Unreliable and overstressed low voltage panelboard replacement Replace 251 of 535 surveyed panelboards, all of which contain NEC code violations.	FY95	\$ 3,100
5.8	Unreliable low voltage feeder replacement Replace deteriorated feeder wire in 21 buildings to upgrade reliability.	FY95	\$ 4,000
5.9	Install SCADA system Install supervisory control data and acquisition equipment for the distribution system.	FY94	\$ 1,000
5.10	Eliminate 12 kV overhead distribution Install remaining 12 kV underground.	FY93	\$ 940
5.11	Distribution automation Add motor operators and SCADA controls to sectionalizing switches.	FY96	\$ 800
5.12	Voltage conversion to 13.8 kV Convert 12 kV distribution to 13.8 kV.	FY94	\$1,100

Project 5.1—115 kV South Main Substation (U-424)

5.1.1 Project Description

This project provides for replacing the existing South Main Substation (U-424) 115 kV system with a new 115 kV gas insulated substation (GIS) having a ring bus configuration as shown on Figures 11 and 12. The substation will have an incoming 115 kV transmission line from the PG&E Tesla substation and a 115 kV transmission line from the Western Livermore Substation (WLS). It can be constructed within the boundaries of the existing substation.

The existing U-424 is 40 years old, and the existing 115 kV bus structure contains two motorized switches which can connect or transfer the main buses to either of the incoming 115 kV transmission lines. There are several limitations to the existing bus structure arrangement. The circuit switchers installed in the bus structure are not rated to interrupt the available fault current from the utilities; the bus configuration does not provide the required flexibility to fully utilize the services from PG&E and Western; the existing configuration does not provide adequate clearances or access for required maintenance.

Replacement of the 115 kV bus structure and associated equipment will correct the cited deficiencies, provide circuit breakers of sufficient interrupting capacity, and provide proper clearances for maintenance and equipment replacement.

The U-424 Replacement Project is a vital element in the Master Plan because it facilitates the parallel operation of Western and PG&E sources of supply to the site.

The WLS and U-424 substations can be operated separately or in parallel and thereby permit serving the load grid switchgear assemblies, unit substations, and other load centers on the site from either or both substations with a minimum of service interruption, thereby greatly increasing reliability.

5.1.2 Service to Cryo Substation from U-424

The Cryogenic (Cryo) Substation is presently served from the 115 kV bus in U-424 through the dedicated 12.5 MVA, 115/4.16 kV transformer. (See Figure 13.)

Cryo substation will be removed from service in early 1994.

5.1.3 Features of the SF₆ Gas Insulated Substation

The general ability of sulfa-hexafluoride (SF₆) gas makes reductions in the size of substations. Three-dimensional configuration of the equipment, as well as the relationship with the transmission system and other equipment connected to it, provides a compact installation which requires only 1/10th to 1/20th of the ground space needed for a conventional type of air insulated substation.

The energized equipment is enclosed in a grounded metal structure, which minimizes the danger of electric shock. Furthermore, since SF₆ is non-flammable, fire danger is eliminated, greatly improving safety. This makes it an ideal choice for installation in areas where space is at a premium.

The completely sealed equipment is unaffected by lightning or other weather conditions, or by corrosion caused by the environment. In the event of internal failure, the gas chambers are compartmentalized for each component, thus preventing damage from spreading and thereby increasing reliability.

The compact equipment reduces the space needed for the substation, thereby producing savings in land costs. In addition, maintenance costs will be dramatically less because all insulators are internal and do not require cleaning.

Insulators and contactors are placed in highly stable SF₆ gas, which provides little deterioration or damage, and maintenance is minimized for the busbar or disconnecting switches. Circuit breakers require an internal inspection only on five-year or longer intervals.

The substation can be made compact, simplifying the work of constructing foundations and erecting support girders. Design and execution of the work is also simplified, and erection time is greatly reduced. Complete sealing of the circuit breakers and overall switching equipment eliminates problems of noise and radio interference.

This project will cost \$5.2 million and is funded by the EPSRU line item.

Fig. 11. Gas insulated substation (GIS) ring bus configuration.

Fig. 12. GIS ring bus—single line.

Fig. 13. The 115 kV overhead line to Cryo, partial LLNL site plan.

Project 5.2—Load Grid Switchgear Assembly Additions

5.2.1 Project Description

These projects will provide for the installation of five Load Grid Switchgear (LGS) assemblies and associated duct banks to replace six area fused substations. One assembly (LGS-37) has been installed to replace one fused substation. The new LGS assemblies are equipped with modern vacuum circuit breakers with relaying for protection. These relays will allow proper protection coordination from the supplying substations to the programmatic loads. This coordination cannot be achieved with the existing fused substation.

The LGS assemblies will have two express feeders as the source of power, one each from U-424 and WLS. Additionally, as a separate

project and at a later date, (EPSRU II) LGS feeders to the programs will be reconfigured to the loop distribution style circuits required by DOE 6430.1A.

These projects include the relocation of existing power factor correction capacitors to each LGS location.

Figure 14 shows the proposed locations for each LGS. The locations have been selected based on existing and proposed load centers and will be sited in accordance with LLNL facility siting criteria.

The estimated cost for these projects is about \$16.5 million with a tentative construction calendar in FY94 and 95. The EPSRU Line Item and Western will fund these projects.

Fig. 14. LGS site layout plan.

Project 5.3—13.8 kV Underground Duct Bank and Manhole Distribution System

5.3.1 Project Description

This project provides for the installation of a 13.8 kV underground duct bank and manhole system throughout the site from the WLS and U-424 to each of the LGS assemblies, which in turn connect to distribution feeders that serve the facility load centers. The underground duct bank system is one of the key elements for distributing power throughout the site.

The usable sections of existing duct banks and associated manholes will be incorporated into the system being installed under this project.

Figure 15 indicates the proposed underground duct and manhole system. The duct bank system is being located along existing utility corridors wherever feasible, and any offsets will be in accordance with LLNL facility siting criteria. Since the duct bank and manhole system is underground and will be located, generally, along existing corridors, there will be minimal permanent impact upon aboveground facilities.

Manholes being installed under this project will be 9 ft × 12 ft × 9 ft deep. Duct banks will contain 6-inch conduit and will vary from four-way to 12-way. Some sections of the underground system will contain parallel duct banks, while

other sections will contain single duct banks. Separation between the parallel duct banks will be designed to minimize the derating of the cable current-carrying capability. The choice of single or parallel duct banks and separation between duct banks was made after a detailed engineering study. Minimum depth below grade will be maintained throughout the system in order to conform to the National Electrical Code (NEC).

The duct banks shall contain spare conduit. Additionally, two sets of 4-inch conduit will be installed for use in communications and protection circuitry.

To select routes for the underground electrical distribution system and avoid existing congested areas wherever possible, many items were considered. One of the items was an alternate layout of the present 13.8 kV underground duct bank system along Avenue B. This possibility was studied but not recommended because of the additional cost and the potential difficulty of installing the duct banks and manholes in this already congested utility corridor.

The funding for this project is included with Project 5.2.

Fig. 15. The 13.8 kV underground duct bank system layout.

Project 5.4 —13.8 kV Express Feeders—Phase 1

5.4.1 Project Description

This project provides for the installation of 13.8 kV express feeders in the underground duct bank system which is to be installed under Project 5.3. The feeders will be installed from the WLS to five Load Grid Switchgear assemblies, LGS-14, LGS-15, LGS-19, LGS-37, and LGS-59, as indicated on Figures 15 and 16.

The express feeders will consist of multiple 750 KCM, EPR cables that terminate on 1200 A circuit breakers in the WLS and in each of the five LGS assemblies. Splices will be installed on the cables only where required.

The estimated cost of this project is \$4.2 million and is included in the \$16.5 million for Project 5.2.

Fig. 16. Arrangement of the 13.8-kV express feeder—phase 1.

Project 5.5—13.8 kV Express Feeders—Phase 2

5.5.1 Project Description

This project provides for the installation of 13.8 kV express feeders in the underground duct bank system which is to be installed under Project 5.3. The feeders will be installed from U-424 to four LGS assemblies: LGS-14, LGS-15, LGS-19, and LGS-59, as indicated on Figure 17.

After the initial set of 13.8 kV express feeders are installed under Project 5.4, each of the Load Grid Switchgear assemblies will be served by a single express feeder from the WLS. This single feeder, or radial-type system, will not have a backup and will require an outage(s) for repair and maintenance. Implementation of the second set of express feeders will permit uptime repair and maintenance and provide an alternate feeder for each LGS assembly. The second set of feeders will increase system reliability in that an automatic transfer scheme will be utilized to transfer an LGS assembly (or assemblies) from the primary feeder, or vice versa, in the event of a fault or loss of voltage on either feeder,

thereby minimizing power outages as well as outage duration.

This second express feeder fulfills the basic requirement of DOE Order 6430.1A that facilities designated as critical shall be served by dedicated redundant circuits.

The alternate feeder also takes full advantage of the rebuilt U-424 and the new WLS. In the event of an outage at either of the main substations or an interruption in the distribution system from either of the main substations to any of the six LGS assemblies, a costly unscheduled outage would occur which could affect large areas of the site. In addition, feeder and equipment maintenance requires downtime, and any downtime adversely affects the programmatic efforts. The installation of the second feeder to each of the LGS assemblies would eliminate most of the scheduled or unscheduled outages and, as clearly indicated by past experience, would be cost-effective.

The project is funded by the EPSRU line item.

Fig. 17. Arrangement of the 13.8-kV express feeder—phase 2.

Project 5.6—Electrical Code Improvements

5.6.1 Project Description

This Project consists of electrical code improvements to the 115 kV and 13.8 kV electric system essentially derived from a Kaiser Engineers survey and report, dated February 1989 (see Appendix A). The study was based on a Code Compliance Survey of the high and medium voltage electric systems at the site, at an estimated cost of approximately \$4.4 million and is funded by EPSRU.

The project is separate from Projects 5.7 and 5.8, which also constitute electrical code improvements. Those two projects apply

specifically to replacement of low voltage feeders and panelboards in buildings.

This project provides the first component of electrical code improvements which are to be conducted in facilities at the site within the five-year plan.

The Kaiser survey was performed in order to provide a basis for defining the items in the high and medium voltage systems that required corrections. A subsequent cost for the individual items was developed from the survey results.

Project 5.7—Unreliable and Overstressed Low Voltage Panelboard Replacement

5.7.1 Project Description

In buildings at the site, a field survey and a short circuit study has been made of the 535 panelboards having 1500 kVA and larger transformers at the 480 volt level and 1000 kVA and larger at the 208 volt level. It has been determined that 251 of these panelboards are underrated and unable to interrupt short circuit faults. This is a violation of the NEC, as well as DOE Order 6430.1A requirements.

The likelihood of panelboard and circuit breaker failures is increasing. This could result in

electrical power disruptions to service and safety hazards to personnel. Breakers are becoming old and obsolete, and some have become non-operational. Failures will affect large areas in the buildings and require considerable service outage time for repair and replacement.

It is planned that all 251 panelboards be replaced under this project.

The estimated cost of this project is \$3.1 million and is funded by EPSRU.

Project 5.8—Unreliable Low Voltage Feeder Replacement

5.8.1 Project Description

A survey has been made of existing feeders in almost all buildings 25 years or older. The feeders to 21 buildings were found to be seriously deteriorated and obsolete.

If not replaced, insulation failures and deteriorations of these feeders will cause increased cable faults and create safety and shock hazards

to operating personnel, as well as increased downtime affecting programmatic service.

It is proposed that the 180 feeders in the 21 buildings identified be replaced under this project.

The estimated cost of the project is \$4.0 million and is funded under EPSRU.

Project 5.9—Install SCADA System

5.9.1 Project Description

This project will install a Supervisory Control and Data Acquisition (SCADA) system at LLNL. The installation of the express 13.8 kV feeders, LGSs and new switching facilities at U-424 and WLS is intended to provide normal service for the Laboratory. The state-of-the-art relaying protection offered by these projects will assure maximum reliability and minimum damage if a fault should occur.

The SCADA system will provide a means for the electric distribution system operator to efficiently provide the following:

- Early identification and resolution of electrical distribution system problems.
- Load transfers from one primary express feeder to another remotely without an outage.
- Optimize the system to safely operate closer to ratings without overloading.

- Information for post-disturbance analysis and load forecasting.

The SCADA system also provides real-time data collection and storage of all monitored load parameters, allowing the planning department access to all system loads such as watts, vars, current, voltage, power factor and DC power availability.

Initially the SCADA system will be installed at U-424, WLS (13.8 kV distribution bus), and the six LGS installations. For a diagram of the SCADA concept and proposed funding sources, see Figure 18.

- The SCADA master control room will be installed in B-517.
- Projects installing new facilities will contain SCADA equipment in the design.
- A SCADA system will also be installed at Site 300.

Supervisory Control and Data Acquisition (SCADA)

*Funding not identified

Fig. 18. Arrangement of the SCADA concept.

Project 5.10—Eliminate 12 kV Distribution

5.10.1 Project Description

This project provides for replacement of the 40- to 50-year old, 12 kV overhead distribution system with an underground 13.8 kV system.

The overhead system has reached the end of its life cycle, and the chances of catastrophic failure increase as it continues to age. The service reliability of the overhead system has not been good. Numerous outages, due to birds and wind, have occurred. Placement of the system underground will resolve its exposure to those elements.

Numerous programmatic loads are served from this system, and they require highly reliable power to successfully complete their assigned missions.

The existing 12 kV overhead system is a radial type, and DOE requirements call for redundant feeds. When placed underground, a loop-style design will be accomplished.

Funding will be accomplished through the GPP process.

Project 5.11—Distribution Automation

5.11.1 Project Description

This project provides for adding SCADA control to existing and future sectionalizing switches. Manually operated switches will be provided with motor operators and mini Remote Terminal Units (RTU) will be added as necessary. This will dramatically reduce the outage time to our programmatic customers.

Upon completion of Project 5.9, the main substation and the LGSs will be SCADA controlled. This will allow not only automatic data acquisition but will also allow for load transfers for maintenance purposes. The completion of Project 5.11 will allow automatic control for the balance of the distribution system.

This project will be GPP funded.

Project 5.12—Voltage Conversion to 13.8 kV

5.12.1 Project Description

This project will convert the 11 remaining 12 kV transformers to 13.8 kV primary service.

The ages of equipment on the 12 kV system vary from 40 to 50 years. The system is beyond its design life expectancy and is subject to failure.

The only remaining 12 kV source, at T-800, failed on its last 12 kV outage. When that occurred, the alternate source, T-300, was still available for use. T-300 has since been removed.

Consequently, an outage exceeding 24 hours would be very likely if another 12 kV outage should occur.

Conversion to 13.8 kV will provide as many as four feeder circuits to feed the area. This would significantly reduce the downtime to the programmatic loads.

This project will be GPP funded.

Appendix A—Studies and Reports

Identification of Previous Studies and Reports

The following is a list of related studies and reports that have been prepared for and by Lawrence Livermore National Laboratory:

Conceptual Design Report, Electrical Power System Replacement and Upgrades (EPSRU) line item, dated February 1989.

Survey and Report: High Voltage Power Distribution System by Kaiser Engineers, dated February 1989.

Report of the Evaluation Committee on LLNL Electrical Power Distribution System, dated March 1989.

Western Area Power Administration Electrical Safety Review, November 1989.

Supplement to the Report of the Evaluation Committee on LLNL Electrical Power Distribution System, dated December 1989.

Electrical Distribution System Peer Review Report by C&L Value Associates, dated December 1989.

Short circuit and load flow studies on the 115 kV, 13.8 kV and 12 kV systems by Applied Power, dated January 19, 1990.

Environmental Assessment for the Electrical Utility System Distribution Replacement and Upgrade, dated October 1991.

LLNL Site Development Plan, dated April 1992.

Site 300 Site Development Plan, dated April 1991.

Coordination studies for the protective devices on 115 kV, 13.8 kV and 12 kV systems by Applied Power, April 8, 1990.

Conceptual Design Report, Electrical Code Improvements line item, dated March 1990.

Report on the current-carrying capability of the 13.8 kV express feeders installed in the underground manhole and duct bank system associated with six LGS installations as well as the alternate seven LGS and eight LGS installations. Several reports dated January through March 1990 were issued. Reports were based on the WE-80 Computer Program, "Calculation of current-carrying capability of 13.8 kV cables in underground duct banks," by West Coast Engineering, Inc.

Electrical Risk Analysis prepared by Impell Corporation, dated January 1990.

Report on the Comparison of 115 kV Breaker Configurations in the South Main Substation, dated October 1990.

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