CHAPTER 4

PACIFIC GAS AND ELECTRIC COMPANY: EARTHQUAKE PREPAREDNESS AND PLANNING

Frances Schultz

The gas and electric utilities supply innumerable public and private services on which we have become dependent. In the major earthquake that will occur one day on the Hayward fault it is unreasonable to expect these services to survive unscathed, though they are particularly necessary following such a major disaster. Natural gas may be necessary for operating emergency generators, while electricity for street-lighting to facilitate rescue activities and for television and radio communication with the public, will be immediately useful. In addition, the level of chaos will be minimized if relatively normal household functions persist, such as lighting, heating, cooking and refrigeration facilities. Recent large earthquakes have caused considerable power outages, which suggests that Berkeley, too, may be temporarily without vital services following a major earthquake.

Damage in Past Earthquakes

The most helpful way to consider what may happen to the utilities in Berkeley during a strong earthquake is to look at what has occurred elsewhere.

In 1964 Alaska suffered an 8.4 Richter magnitude earthquake that caused damage or destruction to virtually all the utilities in south-central Alaska. The initial estimate of costs to the utility company was $25 million, and complete repair required several months. Service to homes and businesses in some areas was restored in two hours, and 90 percent of the system was restored to operation in two weeks.[9]

The four electric power sources for the Anchorage areas were all damaged and power generally failed, largely due to extensive powerline damage. The Chugach distribution system suffered 50 broken poles and 25 fallen pole transformers. Most substations sustained light to moderate damage as a result of vibrations, and in the Turnagain slide area 13 power structures were completely destroyed, and 60 were seriously damaged as a result of toppling or breaking during soil liquefaction.[9]

The natural gas system in Anchorage also sustained heavy damage. The 120-mile long, three-year-old distribution system suffered $1 million worth of damage, mostly in landslide areas. The system sustained over 200 breaks, some in areas where ground displacement was very small. In Seward transmission line damages put the power out of service for over a month, until it was partially restored using small generators. Seven months later it was fully repaired.[9]

The San Fernando earthquake of 1971 supplied the gas and electric utilities with valuable information. The earthquake was moderate, 6.4 Richter magnitude, but damage ranged from light to extensive. More than 24 transmission stations and five distributing stations received varying degrees of damage. The most severely hit of the power facilities were the Olive switching station, where 80 percent of the electrical equipment was seriously damaged and the Sylmar switching station, where 90 percent of the equipment was destroyed. At the Sylmar switching station all 230-V air blast circuit breakers, all 26 disconnect switches and most potential transformers were damaged. All microwave traps, used for intra-company communication, fell from their mounts and some transformers broke through their restraints.[12] Overhead electrical transmission lines generally suffered more than underground cables as a result of differential ground movement, but some underground cables and manholes were badly damaged. Generally, damage was due to inadequate mounting and consequent movement, often resulting in breaks where connections between equipment were not sufficiently flexible. There were many cases where overhead power lines swung together during shaking and burned. Though the gas distribution system often survived in places where buildings did not, the network of welded steel mains in the Sylmar area suffered at least 450 breaks in mains, valves and service risers.[8]

Description of the Berkeley System

The Pacific Gas and Electric Company supplies electricity and natural gas for the Berkeley area. The system is complex but requires only a certain number of essentials for service. The basic units of the electrical system are the bulk power source, generating stations, and transmission and distribution lines. The parts necessary to keep these functional are the transformers, circuit breakers, isolating switches, bus structures (a type of conductor) and a communication system.[12]

Berkeley gets much of its power from the Pittsburg and Contra Costa steam plants to the east of the Hayward fault. These plants are largely housed in braced steel frameworks and were designed with anti-seismic criteria in mind. Natural gas supplies enter the Bay Area via transmission lines that cross the fault at the north and south ends of the Bay and run parallel to its shore in between. These pipelines are made of welded steel and lie in sand-filled trenches that allow them to endure several inches of offset.[12]

Regulations and Standards Regarding Earthquakes

PG&E is regulated in part by the Public Utilities Commission (PUC), whose requirements are not specifically anti-seismic, though they are thought by the Commission to cover earthquake hazards. Transmission lines and pipelines must meet certain structural requirements which in some cases include automatic shut-off valves and disconnect switches in case of line damage. The earthquake problem has been reviewed, and in the opinion of the Commission, is adequately

covered by PUC design criteria, PG&E self-regulation and industrial associations.[11]

The city and county building codes are applicable to the system's buildings and are very similar to the Uniform Building Code. No federal or state codes apply. In the past, PG&E's self-regulation for earthquake resistance has exceeded regulations imposed by the building code, but the building codes have been altered recently, leaving PG&E's criteria only slightly higher than the present criteria of the codes.[13]

A relatively new regulating agency is the California Energy Commission, which regulates the building sites of major facilities other than hydro-electric generating plants. One of its criteria for site selection is the seismicity of the proposed location.[13]

A great deal of seismic regulation is self-imposed by PG&E. Some of their requirements include bolting down cabinets, diagonal bracing of structures, lateral force requirements for all structures, flexible wiring where lines must cross a fault and underground gas mains made of stretchable welded steel. The standards generally apply uniformly to the system, with no special requirements for structures other than transmission lines in known earthquake-prone areas or sites located on the fault. Pipeline criteria are based on moving ground provisions, which are deemed sufficient by the Company. In addition, the Company makes a conscientious effort to avoid building in areas with high probability of landsliding and to avoid putting transmission lines where fault movement is likely to damage them.[13]

Since the 1971 San Fernando Valley earthquake, lateral load requirements have been raised so that substation equipment can withstand greater horizontal and vertical ground accelerations. Substation equipment which is not essential to operation is built to the old standards. Support structures for important equipment are tested for seismic loading capacity and are modified to acceptable capacities if necessary.[12]

In the past few years dynamic testing of equipment has led to modifications of some structures. In a few cases existing equipment has been altered or replaced, but in general, new specifications do not require that existing structures be altered. Frequently, improved anchorage of equipment to its supports is all that is necessary.[12, 13]

In choosing equipment for building or repairing facilities, an engineer may use recent PG&E recommendations on the seismic resistance of parts. The Company has a general seismic policy, but its incorporation is largely left to the individual engineer. However, a committee is now established and meeting to develop a more formal seismic design policy. In addition, PG&E has participated in committees for the discussion and proposal of seismic design criteria, and is installing seismic recording instruments with the aid of a state program.[13]

Predicted Damage in Berkeley

The next major Hayward fault earthquake could be seven or higher on the Richter scale and could produce ground displacement of several feet.[3] Based on past experience, some predictions can be made as to damages that may occur in the Berkeley gas and electric system in such an earthquake.

Some experts are doubtful that natural gas piping can be economically built to withstand large permanent ground movement,[6] and despite the present strong design of the major gas supply lines crossing the fault, they are expected to be ruptured by any major ground displacement.[14] Gas holders, which have held up well in previous earthquakes, will be available to accomodate customer needs while repairs are made.[4] Breaks may also occur in smaller service piping near homes and other buildings, but their repair may be slow since smaller leaks must be reported to the Company before they can be fixed.[4] A supply of gas may therefore be ready, but damaged distribution pipes may interrupt customer service.

Underground electric cables are generally expected to hold up well,[5] but the cables in the fault region may not endure several feet of permanent differential ground movement.[3] When cable breaks are found, overhead electrical apparatus can be set up temporarily, since cable repair is a long process.[5] Manholes separating from conduits has been a frequent problem in past earthquakes and may also be a problem in Berkeley.[12]

Circuit breakers and disconnect switches, which failed in the San Fernando earthquake, could be a problem in Berkeley. If these are not working properly, downed power lines may remain live, unless they can be de-energized from an operating substation.[4] Fallen energized lines would pose serious fire and safety hazards.

Microwave traps used for intracompany communication may fall from their posts as they did in San Fernando. PG&E can also transmit power control signals directly through the power lines,[12] but if the lines are downed, that possibility is eliminated. A radio system would be the only surviving communication mechanism.[5]

Small distribution transformers have now been bolted to the poles on which they are mounted, but even with improved anchorage, these may fall and burn. Larger transformers are not expected to be stopped by their present constraints and may move up to a foot.[14]

Other components of the system that may fail include bus structures, which are essential to electrical distribution and fuel tanks, which if not recently built may buckle or otherwise fail and leak. Switchgear and porcelain insulator damage can contribute further to power failures, and fairly extensive damage is likely to occur to lightning arrestors and filter capacitors.

Experience from the 1964 Alaskan earthquake showed that emergency power sources may also suffer in the shaking. Large storage batteries may be damaged when battery acid spills or when

supports fail. These support systems are usually fairly simple and can probably be designed for greater resistance to earthquake movements. Gasoline or diesel fuel tanks may sever from the lines that connect them to fuel-powered generators, or fuel lines may clog when sediments in the tank are stirred up by shaking. If emergency facilities are kept on the upper floors of a building or support structure, swaying is amplified and danger of damage is increased.[10]

In past earthquakes, spare parts for all kinds of equipment have been damaged when they fell from shelves.[10] PG&E stores spare parts in three or four separate warehouses in the Berkeley area and has an intense safety program for securing and storing all items.[4] Most spare parts are stored on the ground where they would at most topple. Parts on shelves are most likely to be parts for vehicles and other small items hopefully not of immediate necessity.[5]

Emergency Plans

The City of Berkeley Emergency Operations Plan provides that in the event of a disaster, the director of Public Works will become service chief over PG&E to coordinate the allocation of gas and electricity for emergency operations. Further, the Plan stipulates that all utility company employees are to report to their stations in the event of a major earthquake. It provides that existing telephone and radio communication used normally by the Public Works Department will be used, and if all else fails, portable radio and/or runners will facilitate communication. The city's 36 standby and portable generators, which run on gas, will be used for temporary power if their gas lines and tanks are not ruptured.[2]

PG&E focuses a great deal of effort on planning for emergencies. Emergency situations are dealt with every year as a result of severe weather conditions or accidents causing damage to the system, and repairs are carried out as quickly and efficiently as possible.[4] A serious earthquake will be a major test of the PG&E system and its emergency preparations. The most immediate needs following the disaster will probably be shutting off gas mains, repairing downed poles, mobilizing crews and dealing with fires.[5]

Some gas mains have automatic shut-off valves. The flow of gas through the mains can also be shut off manually or by remote control from valve stations.[4] Areas where pipelines cross the fault have been mapped so that breaks can be quickly found following an earthquake.[12] Again, leaks in smaller service piping may be repaired slowly, since they must first be cited and reported. After the San Fernando earthquake some of these went unnoticed for two weeks.[1]

Damage to transmission lines and their accessories is expected to be substantial. Some dangers are eliminated by circuit breakers which cut off electrical flow through damaged lines, but unfortunately these have been damaged in past earthquakes. If substations are operating, power lines may be de-energized and power may be re-routed from the control room, but if both

switches and control rooms are inoperable, fallen lines will remain live.[4]

Personnel and Transportation

Repair necessitates availability of personnel. PG&E crews are alerted to report to work immediately in the event of an earthquake.[5] Assuming all personnel are willing to leave their families, they may have to contend with debris-ridden roads, unusuable freeways and public transportation and possible damaged personal vehicles. Those arriving at work must then be dispatched to execute repairs. Again, road travel may be very slow and difficult. Company vehicles are generally parked outdoors in yards to be relatively safe from falling shelters or debris, and tanker trucks are available to supply the company trucks with gasoline.[12] In general, in the PG&E system, there are no plans for transportation routes designed to avoid road hazards, but the most expedient routes through the city have been determined and mapped for the quickest possible travel. Helicopters may be useful, but the few owned by the company are kept in outlying rural areas. Helicopters for emergency needs may be supplied by the military or civil defense. There are no manpower-sharing contingency plans.

The communication system can be operated on batteries for 72 hours. Communication racks and battery racks have been checked and have been braced and anchored so as to withstand greater horizontal and vertical acceleration at the most important relay stations. Other racks are being investigated and may be strengthened.[12] Since wave traps for intracompany microwave communication may fall as they have in the past, that system cannot be depended on. And because lines may be downed, over-the-wire communication will not be reliable. The radio system remains, and hopefully, its channels will not be overused. In any case, communication between agencies is not expected to be easy using a radio system.[10]

In addition to the shortage or outage of power, damage to the gas and electric system may cause secondary hazards, one of the worst of which is fire. In the 1906 San Francisco earthquake, the three-day fire caused 80 percent of the property loss. And in Tokyo, Japan, in 1923 over 100,000 people were killed, injured or missing due to the earthquake and fire.[12] In the Berkeley area unfavorable weather conditions and the loss of water due to water main breaks across the fault could greatly interfere with the extinguishing of utility-caused fires. PG&E has no contingency plans with the fire department. Since the two units monitor each other's calls, response to fires caused by PG&E equipment is expected to be automatic.[5]

Another important emergency response factor is the availability of spare parts for repairs. As previously mentioned, PG&E feels its replacement parts are safe and accessible. In addition, they are stored in more than one location in case access to one is cut off.[4]

In the event of an 8.3 Richter magnitude earthquake, there would be no way of telling how long service restoration would take,[5] but a report by the United States Office of Emergency Preparedness forecasts many days of recovery.[14]

What to Expect

PG&E is a well-engineered system with respect to seismic hazards. The company's manpower and replacement materials are in good supply, and PG&E response to previous earthquake disasters has been good.[14] The company's testing of structures and updating of anti-seismic recommendations indicate an active interest in earthquake preparedness.

Preparedness, unfortunately, does not mean invulnerability. In the aftermath of a very strong earthquake, general electric power failure and danger from gas leaks can be expected. Repair of the entire system will be a long process, but customers may have their service back in hours or days, judging from past earthquakes. Repairs will be impeded by lack of effective transportation routes and communication and possibly by a shortage of manpower if crews cannot reach their workplaces.

Recommendations

Continued research into earthquake-caused ground movements and the structural flexibility and strength required to withstand those movements may lead to greater seismic durability of the essential system components. For the present, public information on minimizing the dangers in the home due to electrical or gas equipment before and after an earthquake should be given to all customers. Customers should know where and how to shut off the main gas valve in their home and how to close the electrical switch on the main meter box. These actions may be necessary if gas is leaking or electrical wiring is shorting following an earthquake. To reduce potential damage from broken piping and appliance connections, water heaters and other gas appliances should be bolted down or otherwise firmly secured. Flexible connections should be used wherever possible. Customers should be thoroughly familiar with earthquake and utility safety measures and should be prepared to live independently of the utilities for the emergency period immediately following the earthquake.

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