Assessment of electricity supply adequacy for tsunami refuge shelter planning in Universitas Andalas

Arif Budikusuma[1], *Adrianti* Adrianti[1*], *Muhammad* Nasir[1], *Riko* Nofendra[1], and *Nur* Hakimah Ab Aziz[2]

[1]Department of Electrical Engineering, Faculty of Engineering, Universitas Andalas, Padang 25163, West Sumatra, Indonesia
[2]Department of Electrical Engineering, Universiti Teknikal Malaysia Melaka, 76100 Durian Tunggal, Melaka, Malaysia

Abstract. Padang City is an earthquake-tsunami-prone area; therefore, preparedness to anticipate disasters is essential. The city has made evacuation routes and provided Temporary Evacuation Shelters and Final Evacuation Shelters. Universitas Andalas (Unand) is in the safe zone of a tsunami disaster and can be used as a final evacuation shelter. When a disaster occurs, most of the electrical network experiences damage. Hence, only local electrical power supply can be relied on. Unand has gensets and PV that can supply the refugee shelters. This study aims to analyse Unand's power supply ability to provide electricity for planned refugee shelters. The research started with shelter location selection, measuring shelter area, determining shelter capacity, calculating shelter electric demand, and analysing the local supply adequacy in serving the electric demand. The results show that the shelters can accommodate 3704 refugees, and the peak demand is 55.1 Kw in the evenings. The peak demand is far lower than the power supply's maximum output. Then, based on the demand and generating output, power flow simulations are carried out to determine the electrical conditions in the network. It is found that Unand can meet the refugee's electrical power needs and the electricity quality is within standard.

1 Introduction

Padang City is the capital of West Sumatra Province, which, according to geologists, is one of the earthquake-prone areas. This is because Padang City is located between two active earthquake sources, namely the Australian plate and the Eurasian plate. Judging from history, West Sumatra Province has experienced several tsunamis. In 1797, a tsunami disaster was triggered by an underwater landslide due to a previous earthquake. The height of the tsunami waves was estimated at 5-10 meters and about 1 km towards the mainland caused by an earthquake with a magnitude of 8.4 SR [1]. The subsequent tsunami disaster occurred in 1833 and was caused by the rupture of the 1000-kilometre-long Sumatran trench, which produced an earthquake with a magnitude of 9.0 SR. The tsunami had a water height of 2-3 meters [1]. Therefore, preparedness to anticipate disasters is crucial, considering that if a significant earthquake occurs followed by a tsunami, the risk of danger will be very high because Padang City is located on the coast with a relatively high concentration of people living in coastal areas.

One way to reduce the impact of a disaster is to evacuate. Tsunami evacuation methods are divided into two, namely horizontal evacuation and vertical evacuation. Horizontal evacuation is an evacuation carried out by the community by moving away from the coastal area to the tsunami-safe zone. Vertical evacuation is interpreted as an effort to save oneself by moving to a higher place, which can be a hill or a building with more than one floor [2].

Padang City has made disaster management efforts by creating evacuation routes and providing TES (Temporary Evacuation Shelters) and FES (Final Evacuation Shelters). Temporary evacuation sites (TES) are buildings built for tsunami-prone areas as evacuation sites and shelters if a disaster occurs. TES used as evacuation sites are in the form of existing buildings or new buildings dedicated to temporary evacuation sites, or can be natural TES such as highlands, natural or artificial hills [2].

The final evacuation shelters (FES) are places for family members to gather after a disaster occurs and places for refugees to get assistance and carry out daily household activities until the recovery process begins. Activities at the FES are carried out for people who have lost their belongings after the tsunami disaster occurred [3].

Universitas Andalas (Unand) is one of the campuses in Padang City located in the green zone from the tsunami disaster because Unand is situated in a high hilly area far from the coast. In addition, there is sufficient open space, making it a suitable location for final evacuation shelters.

Many of the electricity networks were damaged by the earthquake and tsunami. Hence, the electricity supply was disrupted for several days and even weeks. To obtain electricity for daily activities for the evacuation sites, local generators such as gensets or renewable energy supply such as photovoltaics are needed in the evacuation

* Corresponding author: adrianti@eng.unand.ac.id

site when the power supply from an electric power company cannot be used

On the Unand campus, there are two gensets with a size of 200 KW each and good global irradiation potential for installing solar panels. Unand will install solar panels, which can be used as an alternative energy source to save electricity from PLN. With a large area and adequate facilities such as clean water, generators, and solar panels, Unand can be a final evacuation site for refugees.

This study aims to analyse the adequacy of electrical power from the local power supply available at Unand for the refugees' shelters. To perform this analysis, the total electrical demand at the refugee shelter should be known. The electrical demand is determined by the number of refugees that can be accommodated at the Unand shelter. The number of refugees depends on the available area in Unand as a refuge shelter.

Therefore, based on this sequence of data requirements, the study will have a research sequence:

a. determine the location of the refugee shelter and its area in Unand.
b. determine the number of refugees that can be accommodated at the Unand Shelter.
c. determine the total daily electrical demand at the shelter.
d. analyse the adequacy of electrical power for refugee shelters using local electric power supply at Unand

2 Refugee shelter standards

Based on the area planned as a shelter, 30% is used as open space and public facilities. This figure of 30% is lower than the standard set by Sphere Humanitarian, which is 50% [4]. The open space and public facilities are designed to provide a comfortable and safe environment for the refugees, allowing for recreational activities and the provision of essential services. The 30% area will produce higher electric demand because more refugees can be accommodated. The number of refugees that can be accommodated in an area is calculated using equation (1) for the emergency shelter of UNHCR standard [5]. This UNHCR standard states a living space is at least 3.5m^2 for a person in tropical or warm climates.

$$N_R = \frac{A}{3,5} \tag{1}$$

Where, N_R is refugee number, and A is an area in m^2. In refugee shelters, facilities must be available to meet the refugees' needs. These needs include the availability of electricity, clean water, food, sanitation, and health services.

3 Electricity demand

Electricity in the evacuation site is used for lighting, water pumps for clean water, freezers for storing food, and refugee gadget charging. Lighting consists of indoor and outdoor lighting. Indoor lighting is included in shelters for refugees to stay/sleep and in public spaces such as toilets, bathrooms, and kitchens. Outdoor lightings provide convenient and safe areas surrounding the shelters.

The electrical power requirement for lighting is calculated using the equation (2) and (3)

$$\Phi_0 = \frac{E_v \times A}{\eta} \tag{2}$$

Where, Φ_0 is total luminous flux in a room (lumen), A is the area of the room (m^2), η is lamp efficiency, E_v is illuminance (lux) [6]. The illuminance standard for a shelter room is taken as 250 lux, which is a standard for home lighting in general room [6]. Equation (2) results are used in equation (3) to calculate the required electrical power.

$$P = \frac{\Phi_0}{Efficacy} \tag{3}$$

Where P is electric power consumption (watt), efficacy is lumen/watt.

LED is the most efficient type of interior light bulb at the moment. Therefore, LED light bulbs are used in this planning. Most of the efficacies of LEDs are between 40-80 lumen/watt. Hence, in this research, it is assumed that the lights have an efficacy of 75 lumen/watt [7].

The most common personal gadgets are mobile phones; thus, it is assumed that mobile phones are the only gadgets in the shelters and are owned by the refugees. The electrical energy mobile phones consume is calculated with equation (4).

$$E = P_{phone} \times 0{,}8 N_R \times t \tag{4}$$

Where E is electrical energy in watt-hours, P_{phone} is the average electric power consumed by mobile phone chargings (watts), N_R is the number of refugees and t is the duration of mobile phones charging (hours). The power consumption of mobile phone chargers is around 5 to 25 watts, depending on whether they are slow or fast chargers. The median power of 15 watts is used for the calculation, along with 1.5 hours of daily charging duration. It is also assumed that 80% of refugees use mobile phones daily.

4 Methodology

Research methodology can be divided into four main steps, i.e., the determination of the location of the refugee shelter, the number of refugees, the total daily electrical demand, and the adequacy of electrical power. The details of each step are explained as follows.

4.1 Location of the refugee shelters

The location selection for the evacuation shelter is determined based on the availability of sufficient area and the ability to connect to the Unand underground electricity network. This requirement is based on the 30 September 2009 Padang earthquake, which showed that the Unand 20 kV underground distribution lines did not experience problems due to the earthquake. Therefore, it is assumed that if a tsunami occurs in Padang, the distribution lines are still functioning correctly.

This study used two shelter conditions: 1) Only outdoor and 2) Outdoor and indoor areas. The only outdoor areas are carried out if no buildings are safe after the earthquake. While for outdoor and indoor conditions, it is assumed that some short buildings are still technically feasible for humans to live in.

4.2 Number of refugees

Refuge numbers that the shelters can accommodate are calculated based on the area of the shelter. The area of candidate shelters is measured with the help of Google Maps. Fig. 1. shows area measurement of the Language Centre parking area using Google Maps. Then, the number of refugees is calculated using equation (1) in section 2, where A is 70% of the area that was measured with the help of Google Maps.

Fig. 1. Area measurement of shelter location

4.3 Total daily electrical demand

Electrical demand in the evacuation site consists of lighting, water pumps, a freezer, and mobile phone chargers. These demands are the fundamental electricity needs due to the limited power supply that may be available.

Lighting energy consumption (E) is calculated using the combination of equations (2) and (3) and multiplied by time (t) in hours, which results in equation (5).

$$E = \frac{E_v\,A\,t}{efficacy} \quad (5)$$

The lighting is assumed to be on for 13 hours daily, from 5.00 PM to 06.00 AM.

An electric water pump is required for each shelter location to supply water to the toilet, bathroom, and public kitchen. The pump's electric power consumption is 2000 watts. Each water pump is operated for around seven hours a day. A freezer in a public kitchen is used for food storage and consumption of 760-watt power.

Energy consumption of mobile phones is calculated using equation (4), where the charging time is distributed during the day from 6 am to 9 pm. The scenario of electric power consumption each hour of the day will make the electric load profile of each site. This load profile is then used as load power for power flow analysis using Digsilent Power factory.

4.4 Adequacy of electrical power supply

On the Unand Limau Manih Campus, there are two gensets and Photovoltaic. The gensets have a capacity of 250 KVA each. The photovoltaic systems are located at the Rectorate and Library building, which have a capacity of 149.6 Kwp and 58.3 Kwp, respectively, as shown in Table 1.

Table 1. Power supply for the shelters

Power supply	Capacity	Power factor	Max output (kW)
Genset 1	250 kVA	0.8	200
Genset 2	250 kVA	0.8	200
PV rectorate	149.6 kWp	1	115.2
PV library	58.3 kWp	1	44.9

The maximum power output of PV in the Unand region is approximately 77% of its watt peak, based on experiment results in [8]. Daily PV energy output is calculated from the total yearly PV energy output divided by the number of days a year. The daily energy output is multiplied by a percentage to calculate the hourly power output. The percentage is calculated based on sunny day solar irradiation, where 100% is the total percentage from 7 am to 6 pm, and each hour has a percentage comparable with the hour solar irradiation. The total yearly output of the PV is obtained from a feasibility study conducted by a consultant.

The amount of power from the genset and PV at a particular time of the day is compared with the total demand. The distribution network cannot deliver enough electricity if the demand exceeds the power supply. However, to ensure that the quality of the electricity meets standards (voltage magnitude), a power flow analysis is carried out. Power simulation is executed using Digsilent power factory [9].

5 Results and discussion

5.1 Sites selection and capacity

Site selection is based on the availability of sufficient area, their security and distance to the UNAND underground electric distribution network. The following locations are then selected:

- Outdoor sites: Unand football field, language centre parking area, Convention Hall parking area, Auditorium parking area, library parking area, and Nurul Ilmi Mosque yard. Indoor sites: Convention Hall and Auditorium Building

The area and capacity of refugees from the chosen sites are shown in Table 2. Table 2 also indicates location codes for each site.

Table 2. Area and capacity of shelter sites

Location (code)	Area (m^2)	Living space (m^2)	Capacity (refugee number)
Convention Hall (1)	1017	711,9	203
Auditorium (2)	3433	2403.1	687
Football field (3)	9622	6735.4	1923
Language Ctr parking (4)	365	255.5	73
Convention Hall parking (5)	1215	850.5	243
Auditorium Parking (6)	932	652.4	186
Library parking (7)	1946	1362.2	389
Mosque yard (8)	2696	-	0
Total refugee number			3704
Total refugee number if only outdoor site			2814

From Table 2, it can be seen that no refugee is located in the mosque yard. This is because the mosque will be used as a public kitchen, where food for the refugees is cooked. The biggest shelter is in the Football field, which can accommodate 1923 people. The part of shelter areas not used as living space is used for services such as toilets, bathrooms, and washing areas.

5.2 Electric demand

Lighting is the most significant demand on the sites. Using equation (4) for 1-hour duration of t, the demand for lighting from 5 pm to 6 am is shown in Table 3.

Table 3. Lighting demand

Location	Lighting demand (watt)
Convention Hall	2373
Auditorium	8010
Football field	22451
Language Ctr parking	852
Convention Hall parking	2373
Auditorium Parking	2175
Library parking	4540
Mosque	2710
Total Lighting	45484

The hourly electric consumption of lighting, water pumps, gadget chargers and freezers are calculated for each site. The total electric demand for all outdoor locations is shown in Table 4.

Table 4. Daily electric demand for each outdoor site (kW)

hour	Location code					
	3	4	5	6	7	8
06-07	2.866	2.033	2.11	2.084	2.18	0.760
07-08	3.732	2.667	2.22	2.167	2.35	0.760
08-09	6.329	2.166	2.55	2.418	2.88	0.760
09-10	2.866	2.033	2.11	2.084	2.18	0.760
10-11	3.732	2.067	2.22	2.167	2.35	0.760
11-12	6.329	2.166	2.55	2.418	2.88	0.760
12-13	2.866	2.033	2.11	2.084	2.18	0.760
13-14	1.732	0.067	0.22	0.167	0.35	3.470
14-15	4.329	0.166	0.55	0.418	0.88	0.760
15-16	0.866	0.033	0.11	0.084	0.18	0.760
16-17	1.732	0.067	0.22	0.167	0.35	3.470
17-18	26.78	1.018	3.38	2.593	5.42	0.760
18-19	23.32	0.885	2.95	2.258	4.72	0.347
19-20	24.18	0.918	3.06	2.342	4.89	0.347
20-21	26.78	1.018	3.38	2.593	5.42	0.347
21-22	22.45	0.852	2.84	2.175	4.54	0.760
22-23	22.45	0.852	2.84	2.175	4.54	0.760
23-24	22.45	0.852	2.84	2.175	4.54	0.760
24-01	22.45	0.852	2.84	2.175	4.54	0.760
01-02	22.45	0.852	2.84	2.175	4.54	0.760
02-03	22.45	0.852	2.84	2.175	4.54	0.760
03-04	22.45	0.852	2.84	2.175	4.54	0.760
04-05	22.45	0.852	2.84	2.175	4.54	3.470
05-06	22.45	0.852	2.84	2.175	4.54	3.470

The total electric demand for all outdoor and indoor sites is shown in Table 5.

Table 5. Total demand for outdoor site

hour	Total demand (Kw)	hour	Total demand (Kw)
06-07	16.4322	18-19	48.3788
07-08	18.1044	19-20	50.051
08-09	23.121	20-21	55.0676
09-10	16.4322	21-22	43.9966
10-11	18.1044	22-23	43.9966
11-12	23.121	23-24	43.9966
12-13	16.4322	24-01	43.9966
13-14	6.8144	01-02	43.9966
14-15	9.121	02-03	43.9966
15-16	2.4322	03-04	43.9966
16-17	6.8144	04-05	46.7066
17-18	52.3576	05-06	46.7066

5.3 Supply, demand, and voltage magnitude

From Table 5, it can be seen that the maximum demand is 42.67 Kw, and it occurs from 8 to 9 p.m. The power supply at night is only gensets because there is no battery to store the PV output. Table 1 shows that one genset has a maximum output of 200 kW, which means it is sufficient to supply the demand. During the day, when sun irradiation is high, the highest demand is 17 kW at 11 am – 12 pm. Using PV output data in Table 1, it is possible to employ only PV during the day when the sun is shining. The comparison of demand and the available supply each hour of the day is shown in Fig. 2.

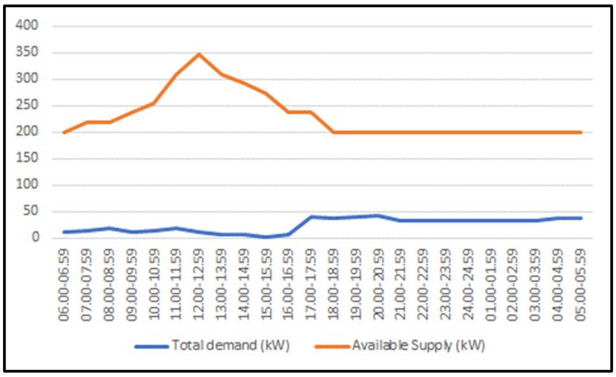

Fig. 2. Outdoor site demand and supply during a day

Since the available generating output capacity is much larger than the demand to be served, the research continues to add more shelter locations. Suppose indoor sites (Convention Hall and Auditorium Building) are included in the calculation. In that case, the demand and power supply graph are shown in Fig. 3. The maximum demand is 55.1 Kw, which occurs at 8 – 9 pm. From Fig. 3, it can be seen that additional demand from indoor sites still results in a total demand that is still much smaller than the available supply capacity.

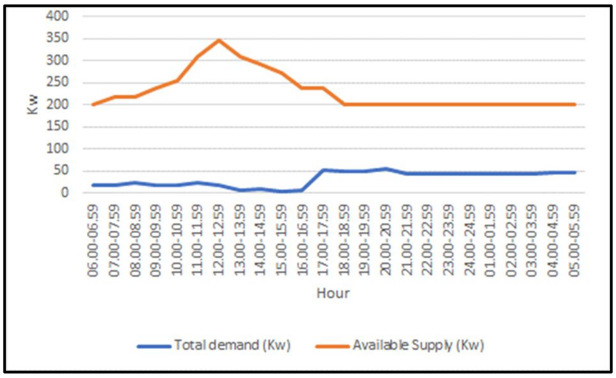

Fig. 3. Indoor-outdoor site demand and available supply

Power flow simulations are carried out to analyse the voltages of each load point in the distribution network. The single-line diagram of the distribution network, which consists of indoor and outdoor refugee shelters, is shown in Fig. 4. The buses of the shelter's electric supplies can be seen in Fig.4 and Table 6. Demand data for power flow simulation are also shown in Table 6.

Table 6. Peak demand for power flow simulation

BUS	Load point /shelter code	kW	kVar
Economy Faculty	2 and 6	12.16	5.89
Animal H Faculty	7	5.423	2.63
Nursing Faculty	3	26.78	18.15
	8	3.47	
	1 and 5	6.216	
	4	1.018	

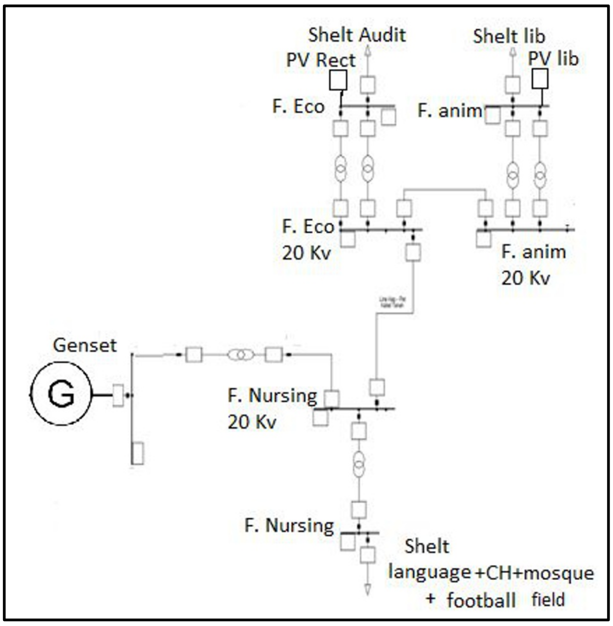

Fig. 4. Single line of Unand distribution network with local power supply and shelter loads

Power flow simulation results indicate that all voltage values are within the permitted standards (in the range of 0.95 -1.05 pu). Unand's electric power supply has greater capacity than the electric demand, i.e. 55.1 kW.

6 Conclusion and future works

The planned shelters can accommodate 3704 refugees using outdoor and indoor sites in Unand Campus Limau Manih Padang. The maximum electrical demand is predicted to be around 55.1 kW, which occurs in the evening. The genset can serve the demand with good electric power quality.

However, since the main power supply is a genset, obtaining diesel fuel might be difficult soon after the tsunami disaster. Therefore, it is suggested that the PV be equipped with a battery for storage of power yield during the day and can be used during peak demand at night.

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