A power demand resilience analysis of the residential and commercial areas for Fengshan smart green community in Taiwan

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Abstract. As global climate change intensifies, extreme catastrophic weather. As a result, the vulnerability of power infrastructure gradually worsens, leading to an increased threat of power supply disruption. In order to cope with the threat of possible power supply disruption and to accommodate more residents in the event of a disaster, backup power generation and storage facilities are necessary should establish in residential and commercial areas. This study establishes a software analysis model of power demand resilience in the residential area, analyzes various power demand resilience scenarios, and discusses the operation of reasonable backup power generation and energy storage facilities, and power load management and control strategies. In the future, these software tools will be used to analyze the rational allocation and operation strategies of disaster prevention at power facilities in similar situations. This study takes the Fengshan Smart Green Community as the reference field, and extends the simulated facilities as the area of power demand resilience analysis, in an integrated residential area and a commercial area. This study has completed four case studies, including: (1) baseline scenario, (2) "use of diesel generators" scenario, (3) "expanding lithium battery capacity" scenario, and (4) "expanding lithium battery capacity and controlling lithium battery power output in the integrated residential area" scenario. The conclusions of this study include: (1) To cope with the intensified global climate change, adequate deployment of various backup power generation and storage facilities to enhance power resilience can effectively mitigate the threat of power supply disruption. (2) According to the case study results, there is sufficient solar photovoltaic in the residential area of Fengshan Smart Green Community. However, the energy storage and power supply capacity of lithium batteries are insufficient, and it is challenging to perform the backup power function. (3) To supply electricity to the power management system and the medical and shelter area adequately, this study suggests Fengshan Smart Green Community strengthens the power storage and power supply capacity of lithium batteries. (4) Solar photovoltaics are zero-carbon power; it can be a priority backup for power demand resilience. However, solar power is not available when there is insufficient sunshine. (5) The use of a diesel generator can flexibly assist the solar photovoltaic and lithium batteries to ensure the adequate power supply. (6) The use of diesel generators for power generation during a time of crisis is not pollution-free. However, their use for management in a crisis or disaster situation is in order when other power supply backups are insufficient or have failed. The critical findings include: (1) Solar photovoltaics are zero-carbon power; it can be a priority backup for power demand resilience. However, solar power is not available when there is insufficient sunshine. (2) The use of diesel generators for power generation during a time of crisis is not pollution-free. However, their use for management in a crisis or disaster situation is in order when other power supply backups are insufficient or have failed.
Keywords: Software analysis model, Power demand resilience, Power load management

1. Introduction
As global climate change intensifies, extreme catastrophic weather, such as strong typhoons or heavy rainstorms, is increasing in frequency. As a result, the vulnerability of power infrastructure gradually worsens, leading to an increased threat of power supply disruption. Residential and commercial areas are relatively densely populated areas. In order to cope with the threat of possible power supply disruption and to accommodate more residents in the event of a disaster, backup power generation and storage facilities are necessary should establish in residential and commercial areas. This study establishes a software analysis model of power demand resilience in the residential area, analyzes various power demand resilience scenarios, discusses the operation of reasonable backup power generation and energy storage facilities, and power load management and control strategies. In the future, these software tools will be used to analyze the rational allocation and operation strategies of disaster prevention at power facilities in similar situations.

2. Methods
This study takes the Fengshan Smart Green Community as the reference field, and extends the simulated facilities as the area of power demand resilience analysis, in an integrated residential area and a commercial area, as shown in Figure 1. The integrated residential area includes a residential area, a medical and shelter area, and a power management system. There are 620 households in the integrated residential area. According to the data of Taipower Company, the daily electricity consumption is 7,979kWh, and the measured power load curve of Fengshan Smart Green Community is adopted. The power supply and power storage facilities for the integrated residential area include a roof-type solar photovoltaic system providing a maximum power of 1,550 kW, and a lithium battery offers a power storage capacity of 400 kWh and a diesel generator power of 500 kW.

A total of 60 small shop users in the commercial area, with total daily electricity consumption of 3,631.8 kWh, are distributed in the commercial area power load curve. The facilities include a roof-type solar photovoltaic system capable of providing a maximum power generation of 600 kW, a lithium battery which offers a power storage capacity of 1,000 kWh, and a diesel generator power of 500 kW.

This research develops a software code as a power-demand-resilience analysis tool. The power demand side includes: (1) a residential area, (2) a medical and shelter area, (3) a power management system, and (4) a commercial area. The power management system manages power supply and storage facilities. The power supply side includes the mains, the solar photovoltaic systems, and the diesel generators. The power supply curves of the solar photovoltaic systems and diesel generators are also the input data prepared in advance, and the lithium battery is an energy storage facility. The lithium battery stores the excess power of the power supply system; When the system power supply capacity is insufficient, the lithium battery is also able to supply power. When the overall system power supply capacity is higher than a specific power load demand, the system supplies power to the specific power demand. When the overall system power supply capacity is less than the specific power load demand, the system supplies power at 0 kW, that is, power terminates from the specific power demand. The power supply range of lithium batteries sets at 20%-80% storage; that is, the available energy storage capacity is 60% of the rated value.

The priority of power supply in the integrated residential area is (1) the power management system, (2) the medical and shelter area, (3) the integrated residential area, and (4) the commercial area. The power management system is responsible for controlling the power supply facilities. Thus it becomes the first priority. The medical and shelter area provides medical care and emergency shelter for the residents and is the second priority.
3. Results

This study has completed four case studies, including: (1) baseline scenario, (2) "use of diesel generators" scenario, (3) "expanding lithium battery capacity" scenario, and (4) "expanding lithium battery capacity and controlling lithium battery power output in the integrated residential area" scenario. The above are scenarios assuming "the mains are terminated at time=2hr, and restored at time = 28hr."

The descriptions of the four case studies are as follows:

(1) The baseline scenario (Figure 2)
Integrated residential area:
There is no solar power when the mains are interrupted, the lithium-battery power supply capacity is 125kW, which is lower than the load demand in the residential area, only for the medical and shelter areas and the power management system. After dawn, solar power is sufficient to restore power to the residential area. After dark, it is no longer possible to supply solar power to the residential area. The lithium battery powers the medical and shelter area and critical loads to time = 18hr (6 pm).

Commercial area:
After the mains are interrupted, the lithium battery continues to supply power, with the solar photovoltaic continuing to supply power from time = 6 hr to time = 17 hr, the lithium battery is exhausted time = 17 hr (5 pm).

(2) The "use of diesel generators" scenario (Figure 3)
There are 500 kW-diesel generators in the integrated residential area and the commercial area individually.

For the integrated residential area: After the interruption of the mains at time = 2hr, the diesel generator provides sufficient power and is complementary to solar energy and the lithium battery. The situation is similar to the commercial area.

This scenario shows that the diesel generators can adequately compensate for the period when the power supply of solar power with lithium battery is insufficient.

(3) The "expanding lithium battery capacity" scenario (Figure 4)
Integrated residential area: The lithium battery storage capacity is assumed to expand ten times that of the original storage capacity, that is, the storage capacity is 4000kWh, the discharge power is 1250kW, the charge power is 600 kW. When the mains are interrupted, the expanded lithium battery supplies power continuously to the area. After dawn, the solar photovoltaic provides power and also charges the expanded lithium battery. After dark, the solar power was terminated at time = 17 hr. The expanded lithium battery outputs power to the residential area, the medical and shelter area, and the power management system until time = 22 hr, because the expanded lithium battery is exhausted.

Commercial area:
The lithium battery storage capacity is assumed to expand to two times that of the original storage capacity, that is, the storage capacity is 2000kWh, the discharge power is 1000kW, and the charge power is 500 kW. When the mains are interrupted, the expanded lithium battery supplies power to the area continuously. After dawn, the solar photovoltaic provides power and charges the expanded lithium battery. After dark, the expanded lithium battery outputs power to the commercial area until time = 25 hr, and then the expanded lithium battery is exhausted.

This scenario shows that the expanding lithium battery capacity can extend the power supply duration for 4 hrs in the residential area. The medical and shelter area and the power management system are still interrupted at time = 22 hr. The power supply duration extends for 6 hrs in the commercial area compared to the baseline scenario after dark.

(4) The "expanding lithium battery capacity in residential areas and controlling lithium battery power output in the integrated residential area" scenario (shown in Figure 5)
For the integrated residential area: the lithium battery storage capacity is assumed to expand ten times that of the original storage capacity. For ensuring the power supply to the power management...
system and the medical and shelter area, the lithium battery will stop supplying power to the residential area as the stored energy is below 60%. During the periods from time = 4hr to time = 5hr and from time = 18hr to time = 28hr, the lithium battery stops supplying power to the residential area, this management successfully ensures the power supply to the power management system and the medical and shelter area.

For the commercial area: the result is the same as that of the "expanding lithium battery capacity" scenario.

This scenario shows that by expanding the lithium battery capacity and controlling lithium battery power output in the integrated residential area, the power supply to the power management system and the medical and shelter area can effectively ensure power supply.

4. Conclusions

The conclusions of this study are stated as below.

To cope with the intensified global climate change and extreme catastrophic weather, adequate deployment of various backup power generation and storage facilities to enhance power resilience can effectively mitigate the threat of power supply disruption.

According to the case study results, there is sufficient solar photovoltaic in the residential area of Fengshan Smart Green Community. However, the energy storage and power supply capacity of lithium battery are insufficient, and it is challenging to perform the backup power function.

To supply electricity to the power management system and the medical and shelter area adequately, this study suggests Fengshan Smart Green Community strengthen the power storage and power supply capacity of lithium batteries.

Solar photovoltaics are zero-carbon power; it can be a priority backup for power demand resilience. However, solar power is not available when there is insufficient sunshine.

The use of a diesel generator with a power supply capacity of 500 kW or more can flexibly assist the solar photovoltaic and lithium batteries to ensure the adequate power supply during the interruption of the mains.

The use of diesel generators for power generation during a time of crisis is not pollution-free. However, their use for management in a crisis or disaster situation is in order when other power supply backups are insufficient or have failed.

The gap of the research is to perform energy resilience analysis on ordinary days. It will be finalized in the near future.
Figure 1: The power supply and demand structure of the Fengshan Smart Green Community

Figure 2: The analysis result of the baseline scenario

Figure 3: The analysis result of the "initiating the diesel generators" scenario
Figure 4 the analysis result of the "expanding lithium battery capacity " scenario

Figure 5 the analysis result of the "expanding lithium battery capacity and controlling lithium battery power output in the integrated residential area" scenario

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