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Research paper

Peak power demand leveling to stabilize and reduce the power demand of dairy barn

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ABSTRACT

In this study, power demand leveling technologies were evaluated through the adjustment of electrical equipment operating times based on the results of a measurement survey on livestock feeding management system electricity usage. The results showed peak power demand at two specific times. One was during milking time, when a pipeline milker, a bulk cooler and other milking equipment were used. In the other case, power demand peaked early in the morning and at night, when electric water heaters were in operation, due to the large number of milking cows and the time-consuming milking method used. In either case, it was found that ventilation fans and other incidental facilities used over extended periods were major consumers and accounted for the base of power demand, and that power consumption would definitely be reduced by peak power demand leveling through adjustment of operational methods for this equipment. It was found that operational control involving the introduction of inverters and the operation of ventilation fans only in parlors and holding areas during milking reduced daily power consumption by utmost 40% on farms with milking parlors and by approximately 30% on farms without. The use of an ice builder to pre-cool raw milk on large-scale farms could reduce daily power consumption by approximately 13%. When combined with the reduced power consumption from operational control of ventilation fans, power consumption could be reduced by over 50%.

1. Introduction

Mechanization of livestock farming industries has helped to free farmers from long hours of work. However, the focus of these industries also underwent a shift to energy-intensive practices due, in part, to long-term low and stable energy prices of fossil fuel. Because it is not necessary to install a plumbing or safety device, the electricity, in particular, is dominant in initial cost, unlike gas and oil fuel. In addition, the use of electricity as a safe energy source is increasing, because the need of bringing fuel into the barn is avoided. Furthermore, it was a significant factor in dairy that electricity was an early lifeline of the recovery in Japan. After the Great East Japan Earthquake of 2011, the importance of decentralized energy systems, sustainable renewable energy use, and the resulting savings in costs were recognized anew.

Among today's renewable energy sources, the introduction and widespread use of biogas for the generation of power in rural livestock farming was expected because the rate of biogas production is less susceptible to natural conditions than other renewable energy sources. Further, in contrast to wind or solar power, biogas is a stable source of electricity with minimal daily fluctuations.

However, electric utility companies must operate power systems that integrate renewable energy under the physical constraints of maintaining a constant balance between supply and demand. To achieve widespread of biogas power generation and reduce operational burdens on electric utility companies, it is necessary to stabilize not only the supply of biogas power but also to sustain the demand electric power in rural areas.

The leveling of power demand in livestock barn management is important for achieving stability in demand, cost savings, and minimal daily fluctuations. Leveling is defined as the management of peak demand to a) avoid concentrated power consumption during certain periods and b) reduce hourly and daily fluctuations in power demand. Leveling helps to disperse such concentrations, lower peak power demand, and reduce power consumption. Further, it contributes greatly to low-cost, low-energy barn management.

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Table 1
Outline of survey target farms.

Farm name	No. of milking cows	Feeding management system	Waste management	Power contract types	
				Three-phase	
				Type	Class
A	71	Tie-stall housing	Barn cleaner	Low-voltage	18 kW
B	181		Barn cleaner	Low-voltage	21 kW, 33 kW
C	212	Free-stall housing	Wheel loader	High-voltage I	57 kW
D	589		Wheel loader	High-voltage I	74 kW, 100 kW
E	452		Wheel loader	High-voltage I	124 kW

The goals of this study are as follows: 1) investigate the methodology for power demand leveling based on surveys of livestock barns, and 2) using simulation, determine the effects of power demand leveling on power consumption.

2. Material and methods

2.1. Survey farms

This survey was conducted in Town S, a leading dairy and livestock-farming region in the Tokachi subprefecture of Hokkaido during a period from November to February. The Town S is named by the initial letter of the respective town, which is used to represent the specific name of the town. It has 20,700 dairy cows and 21,500 beef cattle.

As shown in Table 1, five dairy farms were surveyed. The survey data included the number of cows and feeding management systems. These farms were selected for survey because they reflect the diversity of feeding management systems ranging from Hokkaido's typical family-managed farm to energy-intensive operations using free-stall housing and rotary parlors. One of the farms was a small-scale operation with approximately 100 cows, two were medium-scale farms with 100–200 cows, and the remaining two were large-scale farms with more than 200 cows.

Farm A and B had low-voltage power contracts with the electric power company, whereas Farm C, D, and E had high-voltage power contracts and 6600-V high-voltage power-receiving installations (known as a cubicle) on their premises.

2.2. Investigation methods

Because power consumption is measured on a monthly basis, it was difficult to assess the fluctuations in daily use for each piece of dairy farming equipment. Accordingly, the power consumption for major equipment was determined by connecting data loggers to the power distribution boards at the subject farms. A Clamp On Power HiTester 3168 (Hioki E.E. Corporation, Japan) was used for this purpose. Power lines from three-phase (200 V) and single-phase (100 V) power distribution boards were clamped to measure voltage (V), current (A), and active power (kW) at 1-min intervals for 24 h. The rated output and usage time of equipment on the farms as well as the status of related operations were also investigated using timers and other devices.

Power contracts for each farm varied based on the type of electrical equipment and special electrical installations. Information on the types of contracts was obtained from Hokkaido Electric Power Co., Inc. (HEPCO) with the consent of the farm operators.

2.3. Investigation items

Table 2 shows major equipments for which 24-h power consumption was measured. In this survey, 10 data loggers were used mainly to measure three-phase equipment consumption because single-phase equipment uses less power.

2.4. Leveling of power demand

On farms with high-voltage power contracts, basic electricity rates are determined based on contract demand, which is the 30-minute period during the previous year with the highest average power demand (known as the peak power demand). Because peak power demand increases when more equipment is used simultaneously, an effort was made in the study to level out peaks to minimize the concurrent use of equipment.

3. Results and discussion

Existing power use and demand

Figs. 1–5 show cumulative power consumption by equipment and related temporal changes as measured by data loggers on each farm. For example, farm B data was collected for central ventilation

Table 2
Major equipment used for power consumption measurement.

Category	Products	A	B	C	D	E
Milking Equipment	Compressor	2.2	3.7	4.2	3.0	3.7
	Vacuum milking pump	3.7	3.7	3.7	15.0	15.0
	Milk pump	0.75	0.3	0.75	–	–
	Bulk cooler	3.6	9.9	9.9,8.0	7.4	13.0,4.8
Waste management		1.2	1.8	–	–	–
Feeding equipment	Feed mixer	–	–	–	0.4	–
	Pressure water supplier	–	–	–	–	0.33 (6)
Others	Electric water heater	–	–	–	5.4 (4)	6.4 (6)
	Ice builder	–	–	–	0.37	–
	Chiller refrigeration unit	–	–	–	–	3.7
	Rotary unit	–	–	–	1.2	1.2
	Ventilation fan	0.4 (9)	0.4 (6)	0.4 (56)	0.4 (80)	0.4 (51)

(The number of products).