Energy Planning of Pigsty Using Digital Twin

Seng-Kyoun Jo Dae-Heon Park Hyeon Park Younghoon Kwak* Se-Han Kim

SDF Convergence Research Laboratory
Electronics and Telecommunications Research Institute (ETRI), Rep. of Korea
Email: {skjo, dhpark82, hpark, shkim72}@etri.re.kr
* Building Energy Environment Laboratory, The University of Seoul, Rep. of Korea
Email: ikyh2@uos.ac.kr

***Abstract*—Digital twin as a bridge between the physical and digital world is becoming more attractive with the realization of the industry 4.0. With the deployment of digital twin, pigsty has been replicated and simulated to find out more comfortable feeding environments in the digital world and applies outcomes to pigsty in the real world. In this paper, we propose a use case in the pigsty realized by digital twin and analyze energy related performance under a variety of virtual objects. The results provide the pigsty with criterion on installing new equipments without being installed.**

***Index Terms*—** Digital twin, pigsty, energy planning

I. Introduction

The world's population is expected to increase by 2 billion persons in the next 30 years, from 7.7 billion currently to 9.7 billion in 2050 according to [1]. To provide all the people with enough food, agriculture is becoming the most crucial industry and accordingly, agricultural technology with the combination of ICT is evolving rapidly. The authors of [2] also discussed future agriculture with information technologies and proposed blueprints for farmers.

Digital twin [3], [4] initially originated from the full automation in factories, which configures virtual factories in the digital world, and it manages, operates to estimate the amount of production, the lifetime of components, expected errors during operation, etc. Now the realization of digital twin is extensively used in various industries. As a perspective candidate where it can maximize the benefit by deploying digital twin, we focus on pigsty in the agriculture industry. By building a virtual pigsty in a digital world, it is possible to discover out the best environmental conditions for growth and estimate operational effects during simulations using real and virtual datasets given by pigsty in the physical as well as virtual worlds.

In our previous work in [5], a design concept of a smart pig farm using digital twin for improving animal welfare was proposed for a feasibility study. As a perspective candidate where it can maximize the benefit by deploying digital twin, [5] focused on livestock farming in the agriculture industry. By building virtual livestock farms in a digital world, it is possible to discover out the best environmental conditions for growth including temperature, humidity, CO2, etc. for livestock during simulations using real datasets given by farms in the physical world. In addition, the unnecessary cost due to disease can be minimized.

As an extension of [5], we propose energy planning for pigsty. Energy is one of major concerns in the operation of pigsty and most farmers try to provide pleasant feeding environment as well as not to waste energy cost. To satisfy these requirements, digital twin can be a good approach by implementing virtual pigsty and simulating a number of conditions to find out solutions. The rest of the paper is organized as follows. Section II describes operational aspect of digital twin for pigsty. Section III provides energy analysis including simulation setup and results and Section IV describes conclusion and further works.

II. Digital twin for pigsty

A. *Digital twin platforms*

There are several commercialized digital twin platforms that are widely used in various industries. Predix [6], [7] is General Electric's software platform for digital twin and it collects and analyzes data from industrial machines. It connects data, individuals, and equipment in a standard way. Ditto [8] is an open source IoT platform for digital twin under progress by Eclipse Foundation. It enables a digital twin to be a cloud based representation of real world counterpart (real world things, e.g. devices like sensors, smart heating, connected cars, smart grids, EV charging stations, etc.) by simplifying developing IoT solutions for software developers as they do not need to know how or where exactly the physical things are connected. Watson IoT [9] commercialized by IBM had started as IoT management platform in the early days and is now launching new capabilities to implement digital twin and manage physical things in a digital world. It creates multiple views of products by bringing together various 'digital threads' and data streams that can be tailored to the needs of a particular user.

B. *Digital twin use case*

For the planning of pigsty using digital twin, any digital twin platform described above can be deployed. Instead, we more focus on the interaction between physical and virtual pigsty as shown in Fig. 1. Data (i.e., sensor data, weather data, etc.) from physical pigsty is acquired to perform simulation.

TABLE I: Fan profiles used in study

Model	Power consumption	Air volume (CMH)	Design Flow Rate (m^3/s)	Fan Pressure Rise (PA)
SLF-350A4-6	102 W	3400	0.94	108
SLF-500A4-6	535 W	8500	2.36	227
SLF-730A6-5	660 W	12600	3.50	189
SLF-960A6-3	670 W	19550	5.43	123
SLF-300D2-6	255 W	3568	1.00	257
SLF-500D4-6	418 W	8500	2.36	177

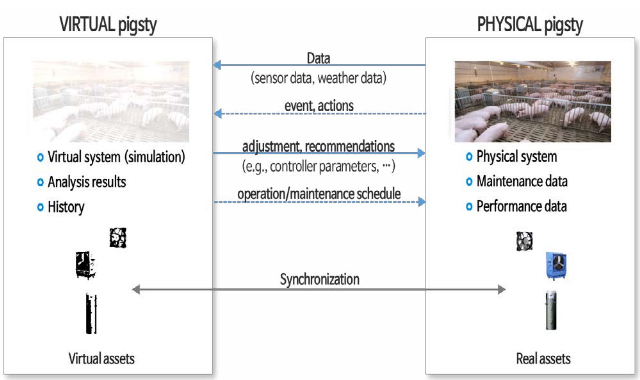


Fig. 1: Interaction between physical and virtual pigsty in digital twin

In addition, event and action are monitored in real or non-real time according to the purpose of simulation. For more active interaction between two pigsties, it is strongly required to understand the status of pigsty by gathering more data.

As a use case how digital twin can be realized in the pigsty, we anticipate performance regarding energy according to various conditions. This is significant when we initially design and construct a pigsty and investigate the performance caused by adding new objects (i.e., fans, heaters, windows, etc.) in the existing pigsty. In order to provide comfortable feeding environments, a variety of factors (i.e., temperature, humidity, CO_2, ammonia, etc.) have to be considered synthetically. As a use case in this paper, we choose temperature as a performance index for energy analysis and other indexes are to be considered as temperature applied. In addition, we include several commercial fans with different capacities described in table. I as virtual objects evaluated in the virtual pigsty. Our goal in this study is to estimate the performance of energy when new fans are installed in pigsty without installing real fans. The result provides farmers with basis for decision in pigsty planning.

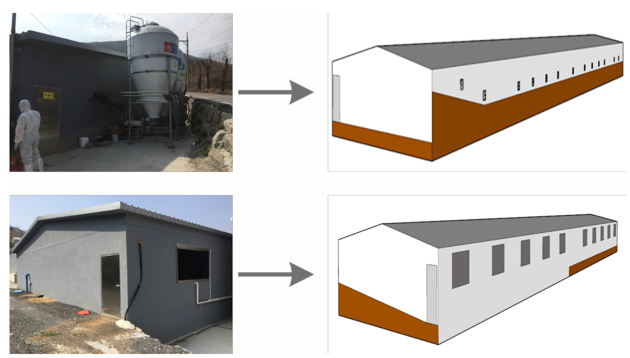
III. Energy Analysis of Pigsty: Planning

For energy analysis using digital twin, more information regarding modelling and simulation setup are described in this section.

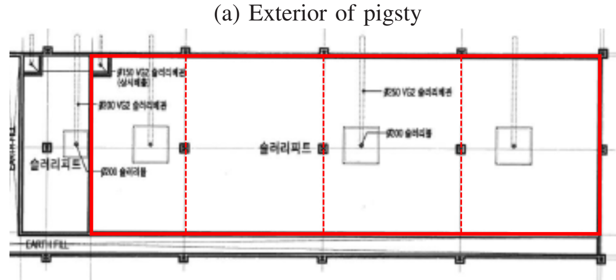
A. Energy simulation setup

To investigate the energy effects through digital twin, we conducted several simulations using an EnergyPlus [10] under the real and commercial pigsty, named as *EcoFarm* located in Suncheon, Jeollanam-do, Rep. of Korea. To evaluate of the energy consumption, we installed weather station in *EcoFarm* and gathered weather data mainly including temperature and humidity. This dataset is used as an input to EnergyPlus with the file format as **.epw* (energyplus weather file).

For the generation of *idf* (input data file) of EnergyPlus simulation, we draw exterior and interior of pigsty using Google SketchUp [11], [12] according to architectural plan and site visit as illustrated in Fig. 2. For exterior modelling, we copy the real pigsty as it considered grounding effect as shown in Fig. 2a. To setup simulation zone for interior design, we tested several cases by dividing 1, 2, 4 zones as shown in Fig. 2b and the preliminary results in table. II showed minute difference in the area of cooling & heating panel required to install. Consequently, we assume to have 1 zone in pigsty.



(a) Exterior of pigsty

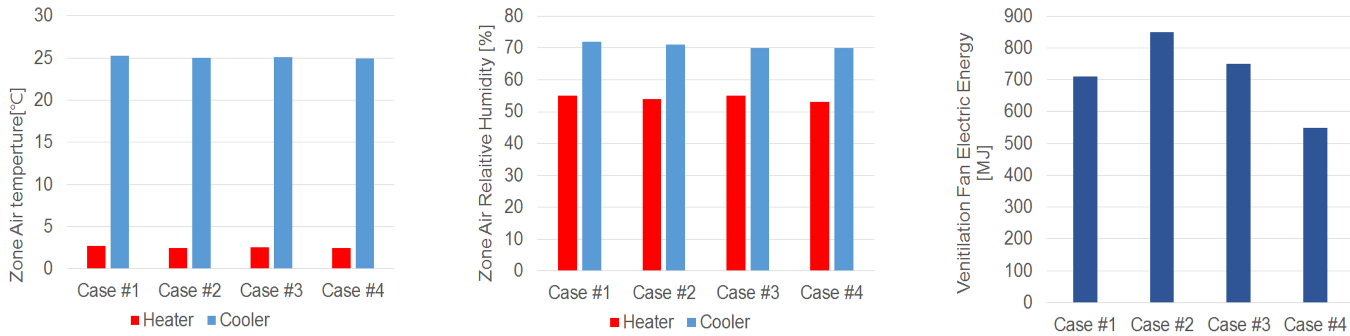


(b) Interior of pigsty

Fig. 2: Modeling of pigsty

TABLE II: Preliminary results

The number of zone	Cooling & heating panel per zone (m^2)
4	10.3725
2	20.745
1	41.49



(a) Average pigsty temperature

(b) Average pigsty relative humidity

(c) Ventilation fan electricity energy

Fig. 3: Energy performances

Table. III shows 4 cases with different combinations of fans to investigate energy usage.

TABLE III: Simulation cases

	Fan combination	ea	Total CFM
Case #1	SLF-350A4-6 (15ea), SLF-300D2-6 (10ea)	25	51000
Case #2	SLF-500A4-6 (6ea), SLF-500D4-6 (4ea)	10	50000
Case #3	SLF-730A6-5 (4ea), SLF-500D4-6 (4ea)	8	49600
Case #4	SLF-960A6-3 (4ea), SLF-300D2-6 (2ea)	6	50000

B. Results

Under these conditions, we measured the energy related performance of given 4 cases. Figure. 3a and Fig. 3b illustrate the temperature and relative humidity in the pigsty according to the operation of heater and cooler under given cases. As shown, there is no major difference among cases due to the fact that temperature and relative humidity are strongly depend on the amount of airflow.

Even though there is any significant difference in temperature and relative humidity, the ventilation fan electricity energy shows more difference among cases as shown in Fig. 3c. Among given cases, it can be said that case #4 consist of 6 fans consumes less electricity and this combination of fan is recommended to equip new fans in the pigsty planning.

IV. Conclusion and Further Works

To provide comfortable feeding conditions in pigsty, energy planning is one of critical concerns in operation. With the convergence of various ICT technologies, it becomes to be more realistic and easy to control. In this study, we used digital twin for the realization of interaction between physical and virtual pigsty. As a use case, we chose fans and combine several fans with different capacities, then compare energy consumption. The results implies the expected energy usage and the guideline to install new fans in the pigsty, actually not being installed.

As a further work, we extend the objects such as cooler and heater with different capabilities to investigate the effect to the pigsty. Also more interaction between 2 pigsties will be considered for the active realization of digital twin in the pigsty.

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