Simulation of Windmill

CS352: Computer Graphics
& Visualization Lab

Project Report

Course Instructor:

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Introduction

Windmills have existed in the countryside for a long time. They harness wind to generate energy that humans may use again and again. Windmills have evolved over time to be more visually appealing and functional. Nowadays, they are more modern and efficient. Computer images let us perceive and comprehend these developments. They allowed us to create images that depict how windmills work and how they look.

In our project, we will create a simulated windmill using a computer tool called OpenGL. We can use OpenGL to simulate the windmill rotating and reacting to the wind. This report will show how we built the pretend windmill and why it is useful. We will also discuss how it can help people learn about wind energy and enjoy seeing how windmills work.

The simulation of windmills in computer graphics serves multiple purposes. Firstly, it offers a means to study the dynamics of wind energy conversion, allowing engineers and researchers to optimize design parameters such as blade shape, pitch angle, and tower height for maximum efficiency.

Secondly, it provides a visually engaging representation of windmill operation, which can be utilized for educational purposes to illustrate concepts of renewable energy and engineering principles. Lastly, it presents an opportunity for artistic expression, enabling designers to create immersive virtual environments that showcase the beauty and functionality of wind energy.

In this project, we aim to develop a simulation of a windmill using OpenGL, a widely-used graphics library for rendering 2D and 3D computer graphics. By leveraging OpenGL's capabilities, we will create a dynamic representation of a windmill, incorporating elements such as rotating blades, realistic wind effects, and interactive controls. Through this simulation, viewers will gain a deeper understanding of the mechanics behind wind energy generation and experience the captivating allure of these iconic structures in a virtual environment.

This report outlines the process of developing the windmill simulation, including the design considerations, implementation details, and insights gained from the project. Additionally, it discusses the potential applications of the simulation in education, research, and entertainment, highlighting the significance of computer graphics in advancing our understanding and appreciation of renewable energy technologies.

Specifications

Libraries used:

1. <GL/gl.h>:
    - This header is part of the OpenGL (Open Graphics Library) API.
    - It contains declarations for OpenGL functions, constants, and types used for rendering 2D and 3D graphics.
    - It's typically used in C or C++ programs that utilize OpenGL for graphics rendering.
2. <GL/glut.h>:
    - This is the OpenGL Utility Toolkit header.
    - It provides a platform-independent API for creating graphical user interfaces and handling input/output operations in OpenGL applications.
    - GLUT simplifies the process of setting up OpenGL environments and handling user input events.
3. "SOIL.h":
    - This header is part of the Simple OpenGL Image Library (SOIL).
    - SOIL is a small and easy-to-use library for loading images in various formats for use in OpenGL applications.
    - "SOIL.h" contains function prototypes and constants necessary for using SOIL's image loading capabilities in your program.
4. <bits/stdc++.h>:
    - This header includes a lot of standard C++ headers like <iostream>, <vector>, <algorithm>, etc.
    - In a computer graphics project, you might use it for general-purpose programming tasks, such as data structures (like vectors), input/output operations, and algorithm implementations.

How to run the Project:

1. **Download and Extraction:**
    - Download the project Zip file from the provided link.
    - Extract the contents of the Zip file into a folder on your local machine. Ensure that the extracted folder contains the required CPP files and the settings icon image.

2. **SOIL Library Installation:**
    - Open a terminal window.
    - Execute the following command to install the SOIL library:
      ```
      $ sudo apt-get install libsoil-dev
      ```

3. **Compilation and Execution:**
    - Once the SOIL library installation is complete, navigate to the folder where you extracted the project files using the terminal.
    - Compile the main CPP file (e.g., Product.cpp) using the following command:
      ```
      $ g++ Product.cpp -o product -lGL -lGLU -lglut -lSOIL
      $ ./product
      ```
4. **Viewing the Project:**
    - Upon running the executable, a window will appear displaying the project.
    - Explore the project using various keys as indicated in the program's interface.

Key Controls:

KEY	FUNCTIONALITY
e	To translate left
f	To translate right
g	To translate down
h	To translate up
i	To translate outwards
j	To translate inwards
n	To change the day/night mode
A	To increase speed of wind which also increases rotation speed of blades
a	To decrease speed of wind which also decreases rotation speed of blades
<,>	To zoom in and zoom out the whole view respectively
X,x	Rotates anticlockwise,clockwise along X-axis respectively
Y,y	Rotates anticlockwise,clockwise along Y-axis respectively
Z,z	Rotates anticlockwise ,clockwise along Z-axis respectively
C,c	Rotates the head of the windmill from left to right and right to left respectively
B	To change the mode into Manual mode
l,m	To go to next and previous view respectively
R,r	Converges and diverges the blades respectively

Functionalities :

Our project revolves around the intricate details of the windmill, aiming to offer a comprehensive experience with a multitude of functionalities. Below, we delve into the different functionalities that we developed and a brief description about each of them.

Implemented Functionalities:

- **Rotation of Windmill Blades:** Users can control the direction of windmill blade rotation by changing the direction of wind , allowing for both clockwise and anticlockwise rotation. This adds interactivity and customization to the simulation.

- **Clouds Movement:** We designed the clouds by arranging the spheres in a particular fashion. The clouds dynamically respond to the wind direction and the wind speed, enhancing the realism of the environment and simulating the influence of wind on the surroundings.The clouds translate faster as the wind speed increases and in the direction of wind.

- **3D Simulation with Translation:** The simulation offers full 3D capabilities with translation in all directions, providing a comprehensive view of the windmill and its environment from various angles.

- **Night Mode:** Users can switch between day and night modes, altering the lighting and ambiance of the scene. This feature adds versatility and aesthetic appeal to the simulation.We added the moon and stars in the night mode for better visual appearance.

- **Road**: Addition of a road in between houses creates a more realistic urban environment. We added lane markers on the road to make it a bit more authentic.

- **Street Light**: We added a street light next to the road creating a more immersive and detailed scene. We designed the street light using two cylinders and a hemisphere. We added the functionality to view these newly added objects separately.

- **Glowing Street Lights**: Street light illuminates and glows giving out a yellow light during the night mode, contributing to the ambiance and enhancing the visual experience.The position of the light source is fixed at the same place where the bulb of the street light is placed.

- **Menu Updates and Integration**: The menu has been updated to incorporate new features such as the road, street lights, and options for day/night mode. The integration of these elements seamlessly enhances user interaction and control over the simulation.

- **Objects Viewing in Night Mode:** Users can view any object separately in the night mode. All the functionalities of that object can be applied for better analysis.

- **Enhancements to Existing Features**: Efforts have been made to improve existing features, including adjustments to object positioning, color changes, changes to the background and other modifications to refresh the overall appearance and functionality of the project.

- **Energy - Wind Speed Relation**: We revised the equation that calculates the energy generated based on varying wind speeds.

Existing features:

- **Manual and Auto Mode**: Users can switch between manual and auto modes to control the windmill's behavior either manually or automatically. Users can increase or decrease the speed of the wind in manual mode with change in cursor movements.

- **Convergence and Divergence of Windmills**: The simulation includes features for windmills to converge or diverge based on user preferences or predefined settings.

- **Rotation of Windmill Head:** Windmill heads can rotate, adding another layer of realism to the simulation and allowing for dynamic adjustments.

- **Rotation About X, Y, Z Axis:** Users can rotate objects about the X, Y, and Z axes, providing flexibility in viewing and manipulating the windmill and its surroundings.

- **Basic Environment:** The simulation includes a basic environment like the terrain, houses and transformer and mountains , providing a context for the windmill and enhancing the overall realism of the scene.

- **Object Viewing:** Users can separately view objects present in the project, allowing for detailed inspection and analysis.

- **Multiple Views:** Six different viewing angles are available, including top view, hill-side view, front view, close-up view, side-left view, and back view, offering diverse perspectives for observing the windmill simulation.

- **Glowing of Lights :** When the windmill starts rotating at a significant speed one can notice the lights through the windows and the cupola. The intensity of the light increases as the speed of the windmill increases. This represents the electricity generated in the windmill is being used to supply electricity for the household.

- **Menu :** This menu guides the user to operate smoothly. It consists of different views available, mentions about the objects present in our model, allows the user to change between auto and manual mode and day and night mode , gives the user an option to view the instructions,

- **Zoom In/Out:** Users can zoom in or zoom out to have a clear look at the different objects and to analyze various aspects of the elements.

- **Information Box** : This displays the current windmill speed and the energy generated.

- **Depth Testing:**Enabled depth buffer and depth testing for achieving a realistic 3D effect and facilitating hidden face removal.

- **Lighting:** Implemented lighting effects with the sun as the light source.Light source considered at infinity, with direction set for global illumination.Normals at polygon surfaces used for shading effects.Material function applied for surface properties such as shine and ambient light.

Output

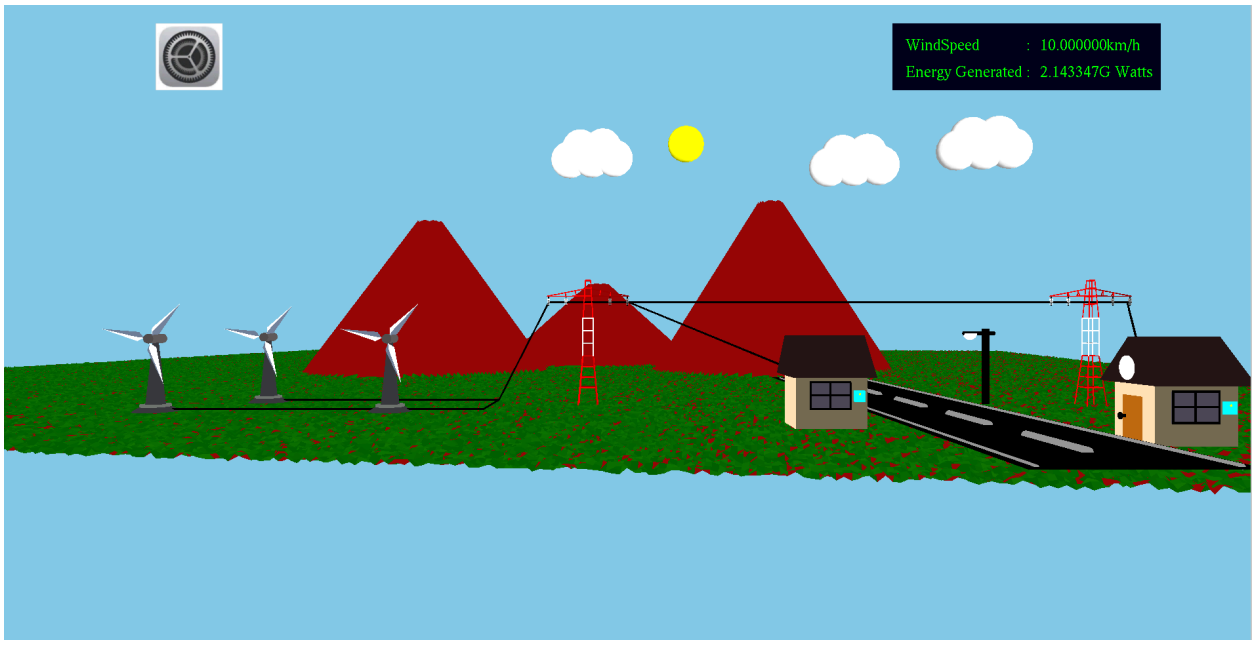

Fig. Front view of the windmill system

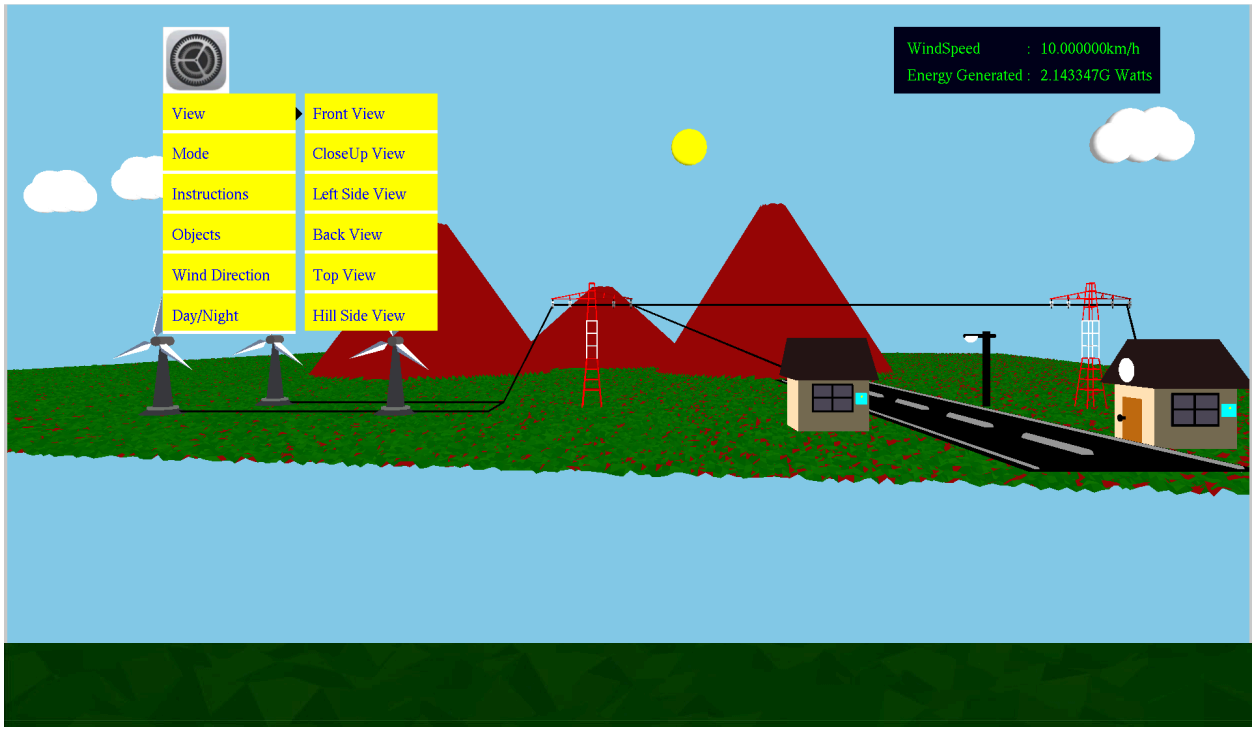

Fig. Demonstration of view options in Menu

Fig. Closeup view of the windmill

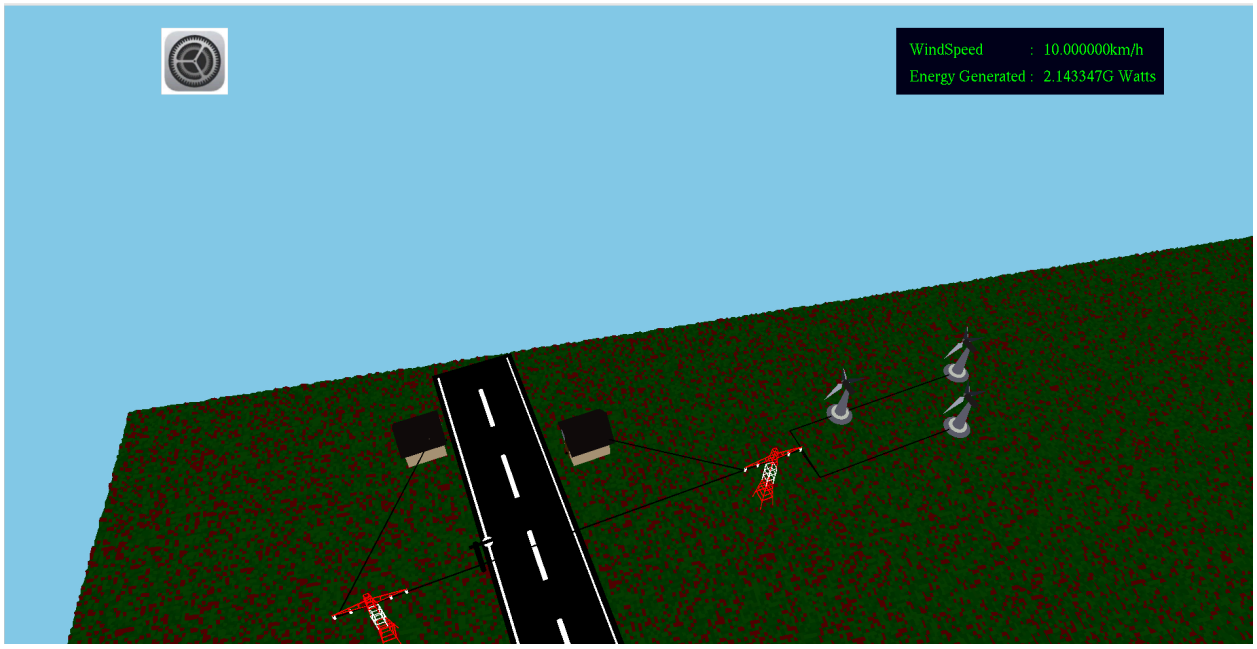

Fig. Top view of the windmill

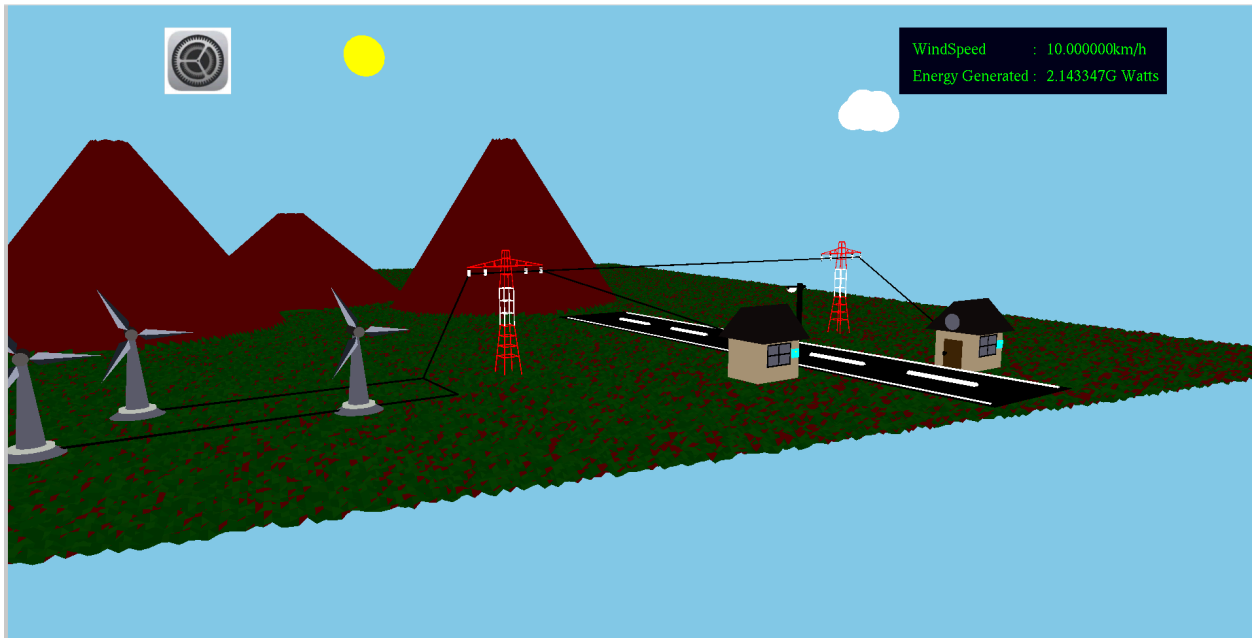

Fig. Side Left view of the windmill system

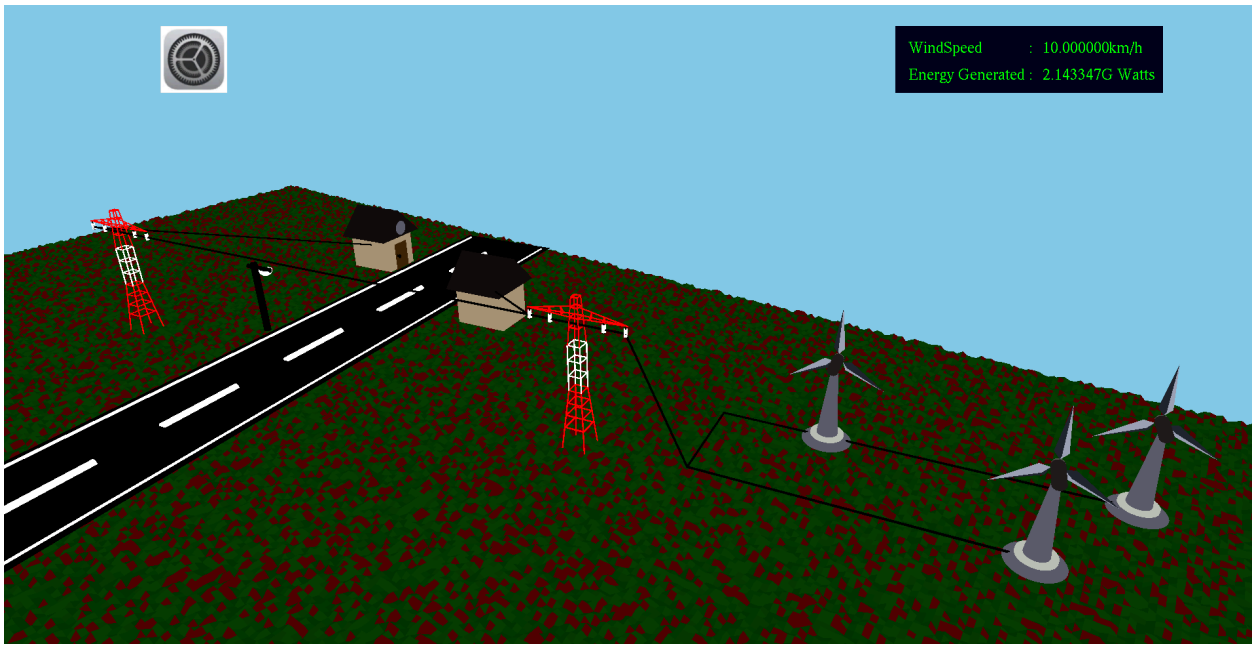

Fig. Back view of the windmill system

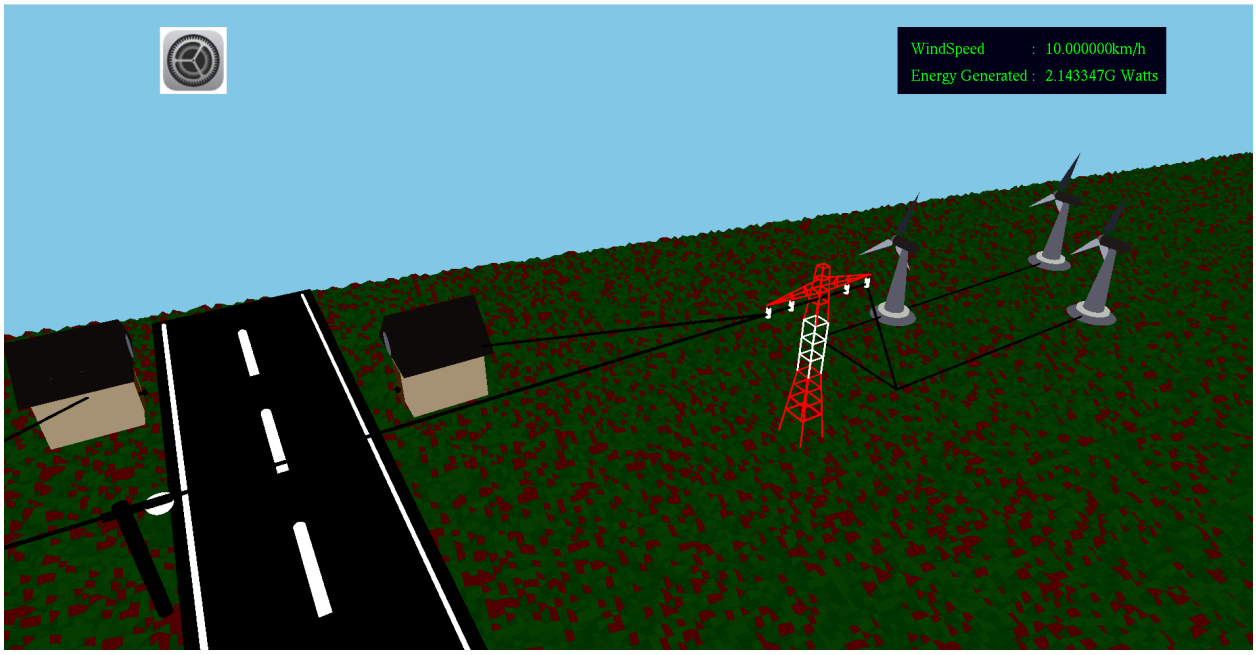

Fig. Hill side view of the windmill system

Fig. Instructions

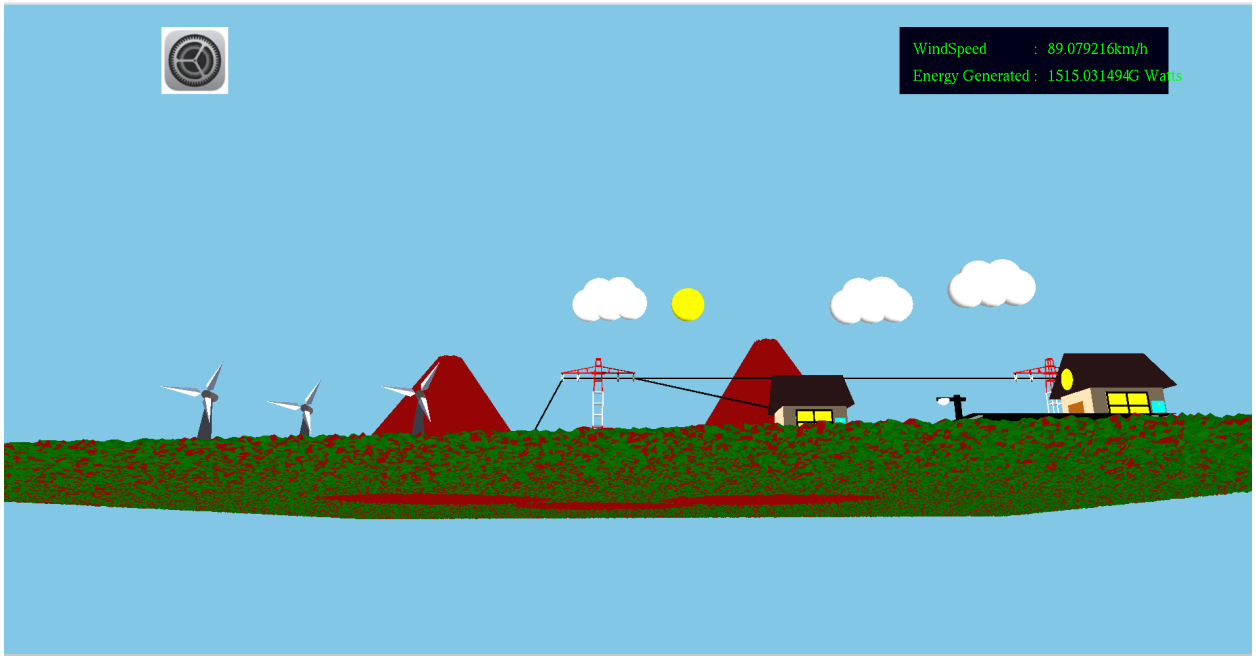

Fig. Anti-clockwise rotation about X - axis

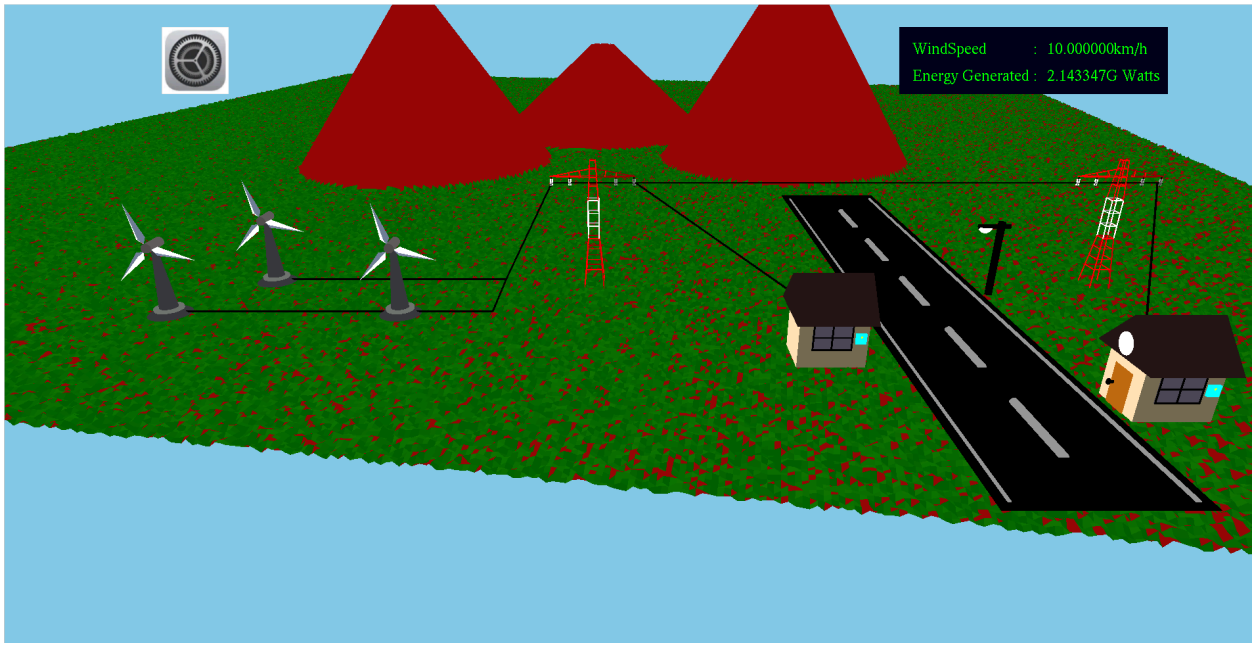

Fig. Clockwise rotation about X - axis

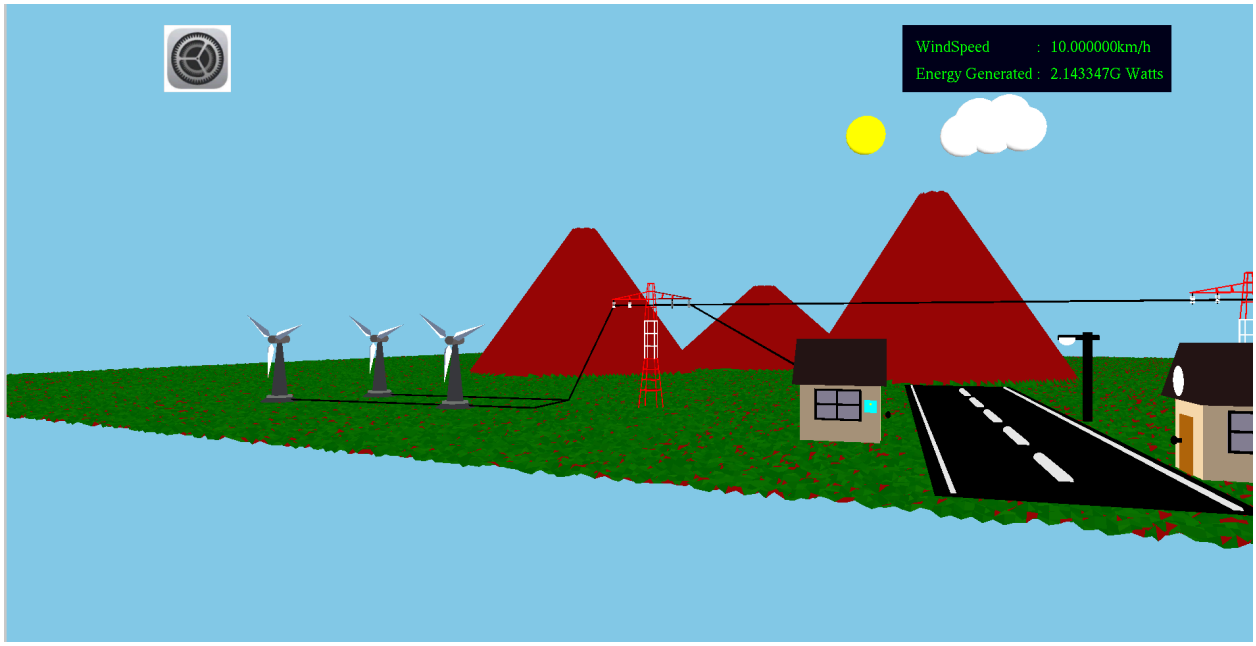

Fig. Anti-clockwise rotation about Y- axis

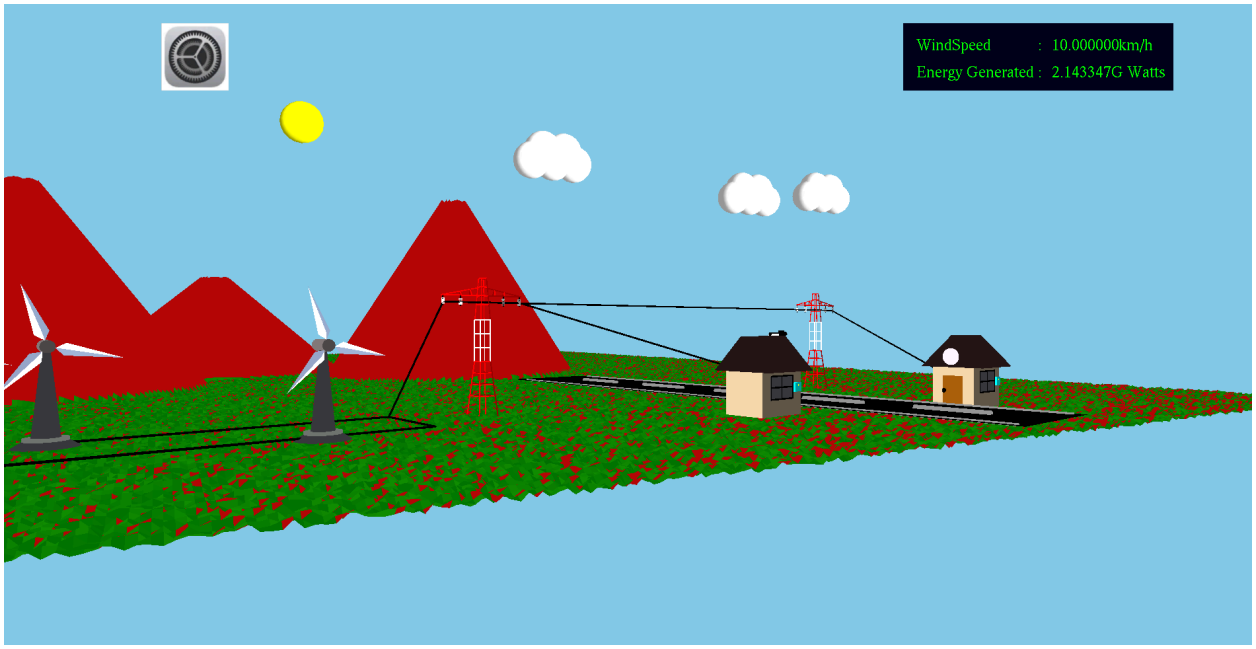

Fig. Clockwise rotation about Y-axis

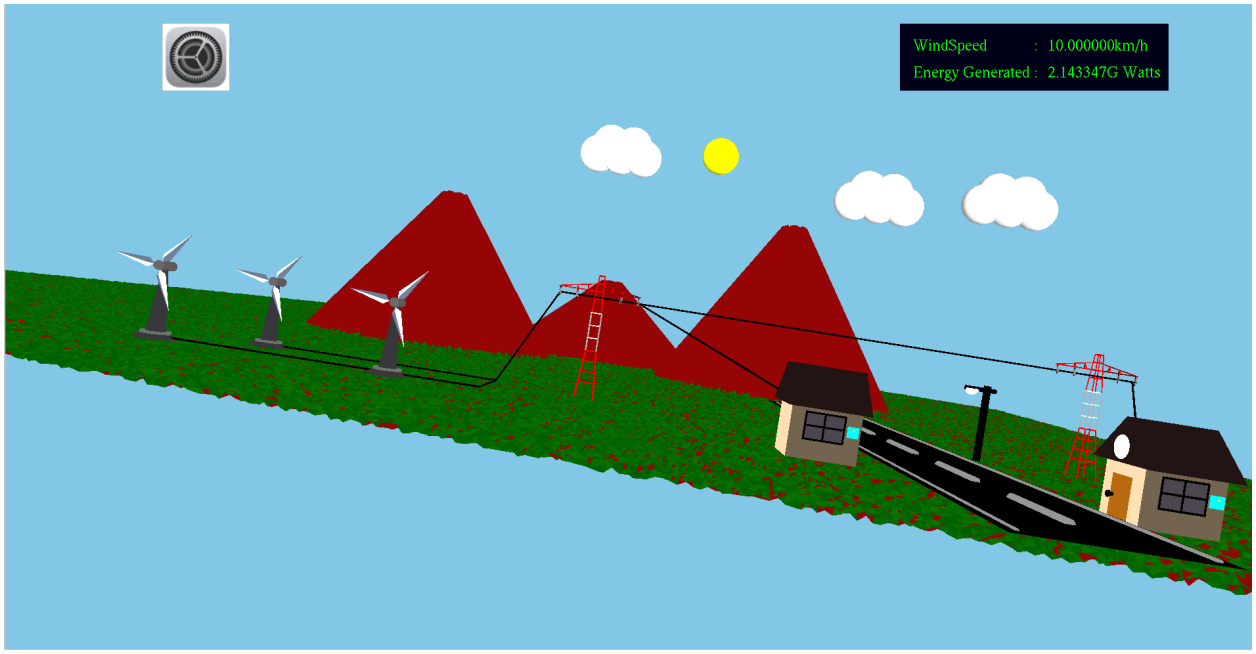

Fig. Clockwise rotation about Z - axis

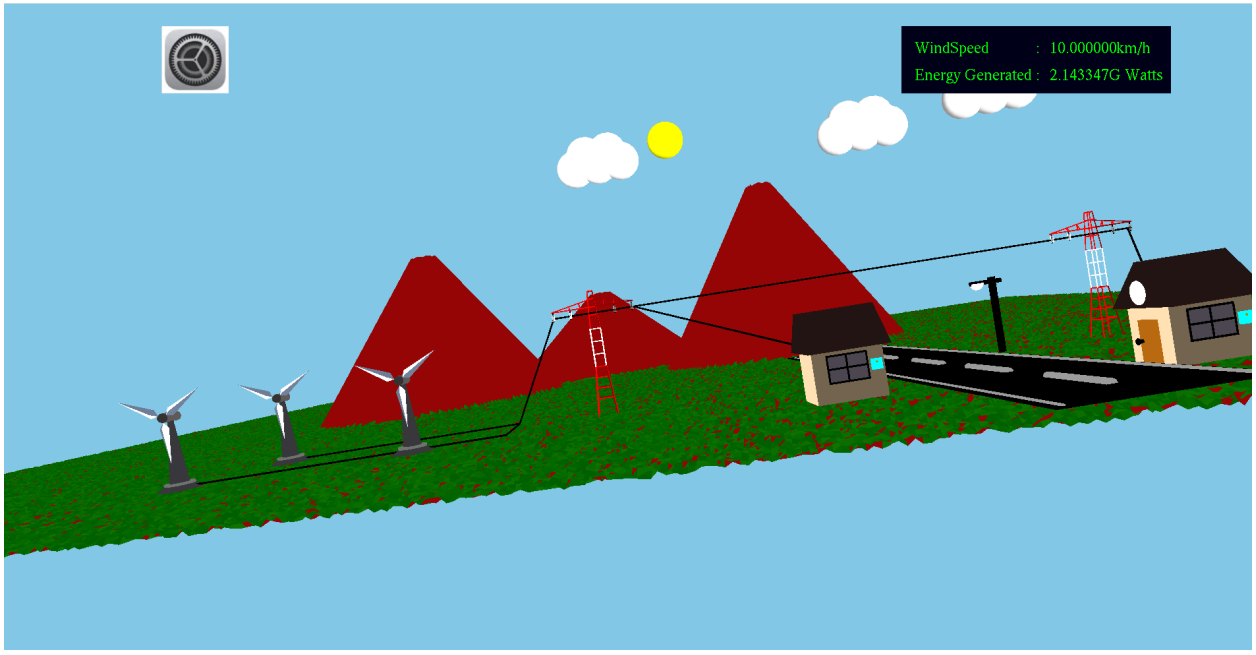

Fig. Anti-clockwise rotation about Z - axis

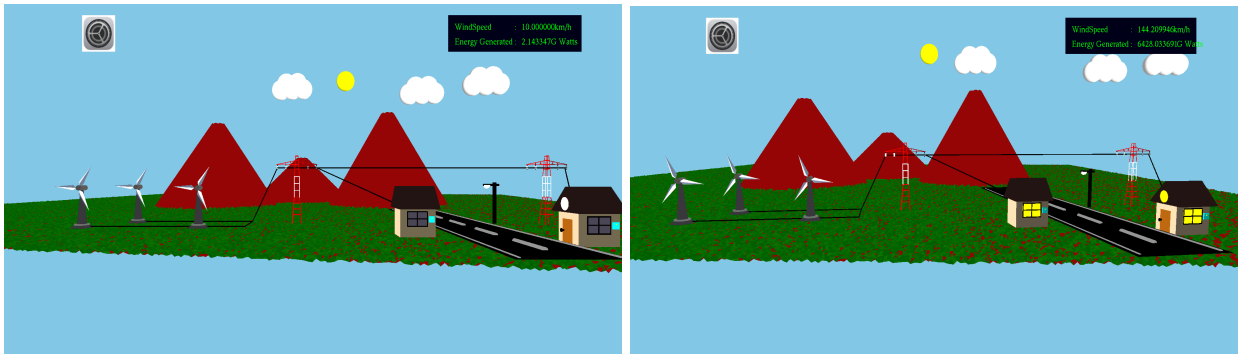

Fig. On increasing wind speed (lights on)

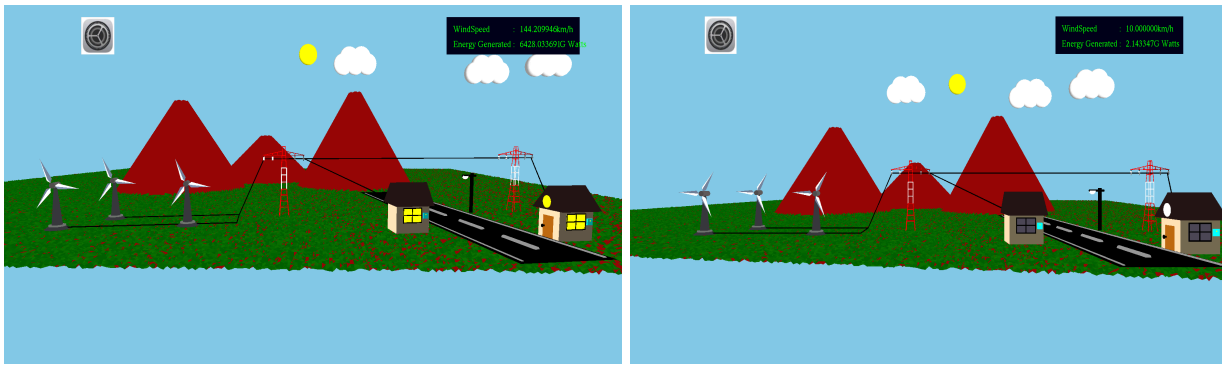

Fig. On decreasing wind speed (lights off)

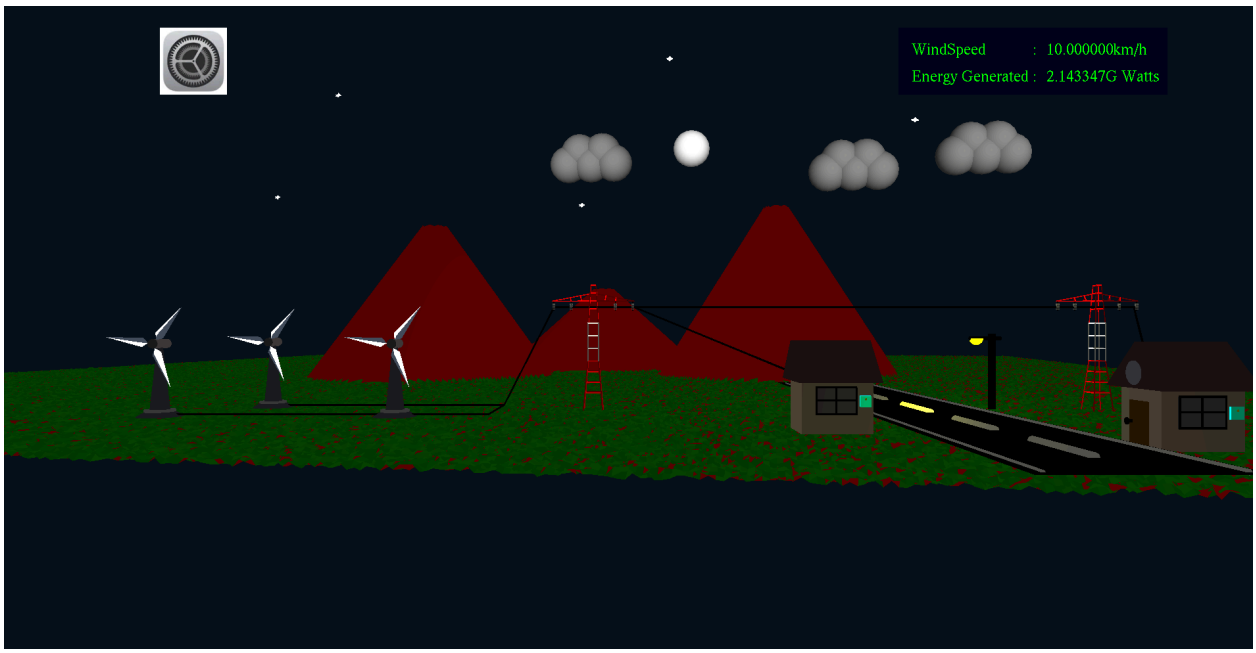

Fig. Night mode

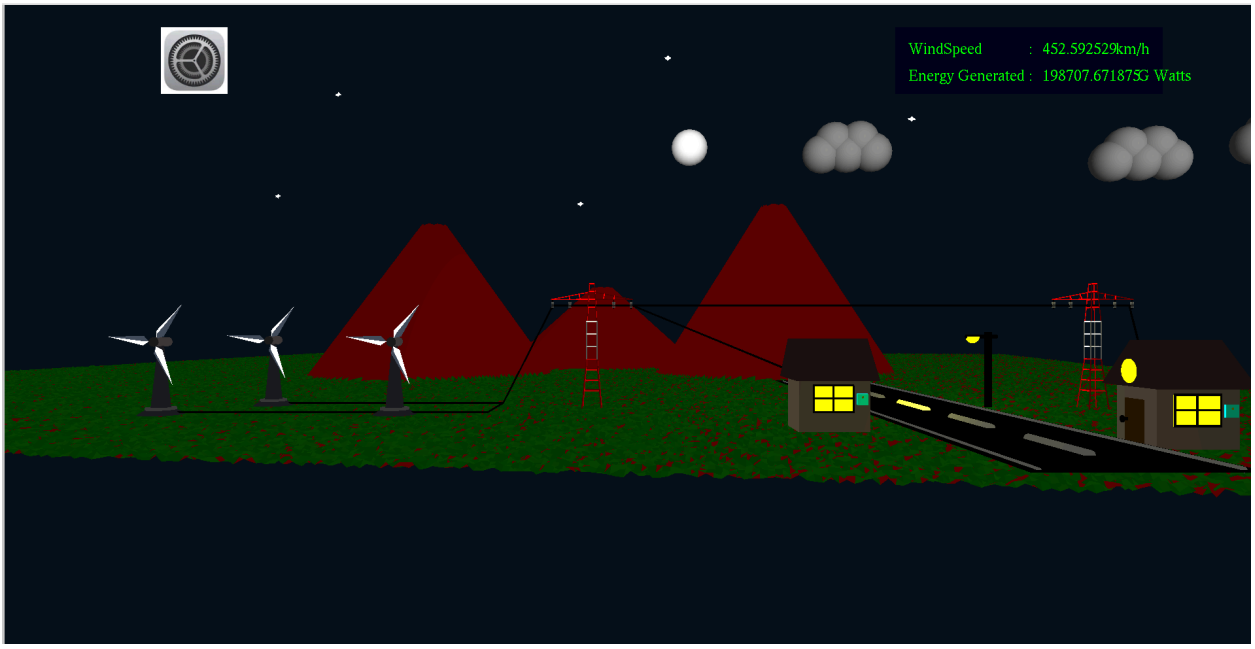

Fig. On increasing speed (lights on)

Fig. Windmill Object

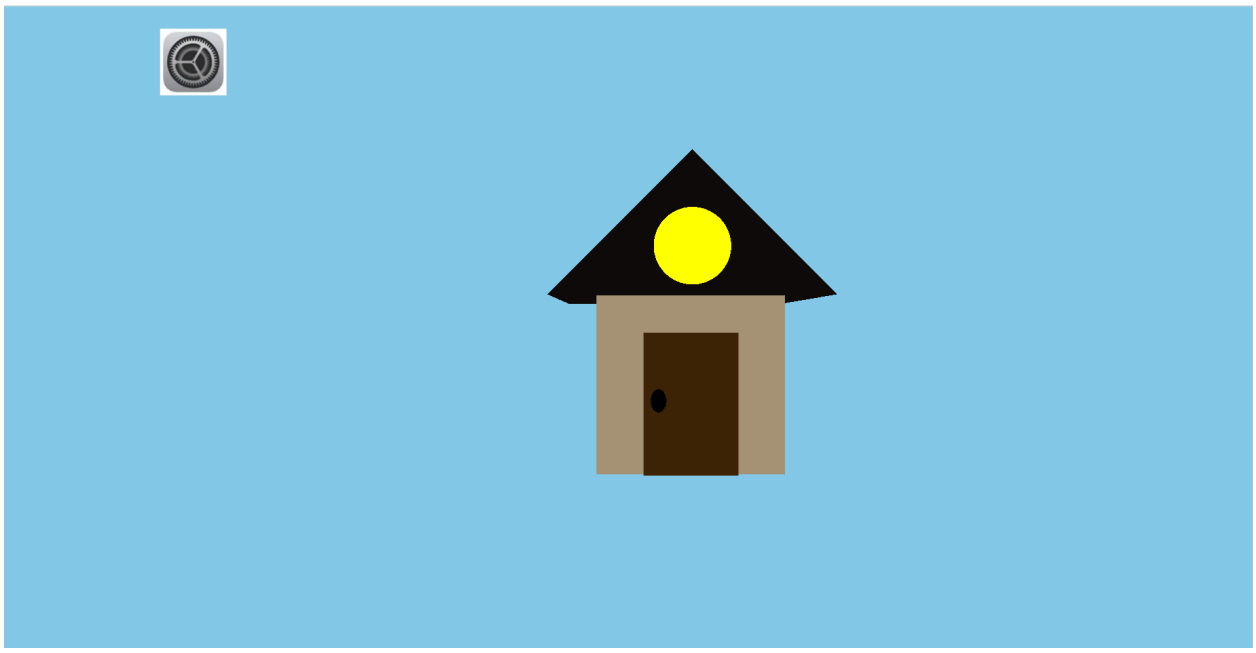

Fig. House Object

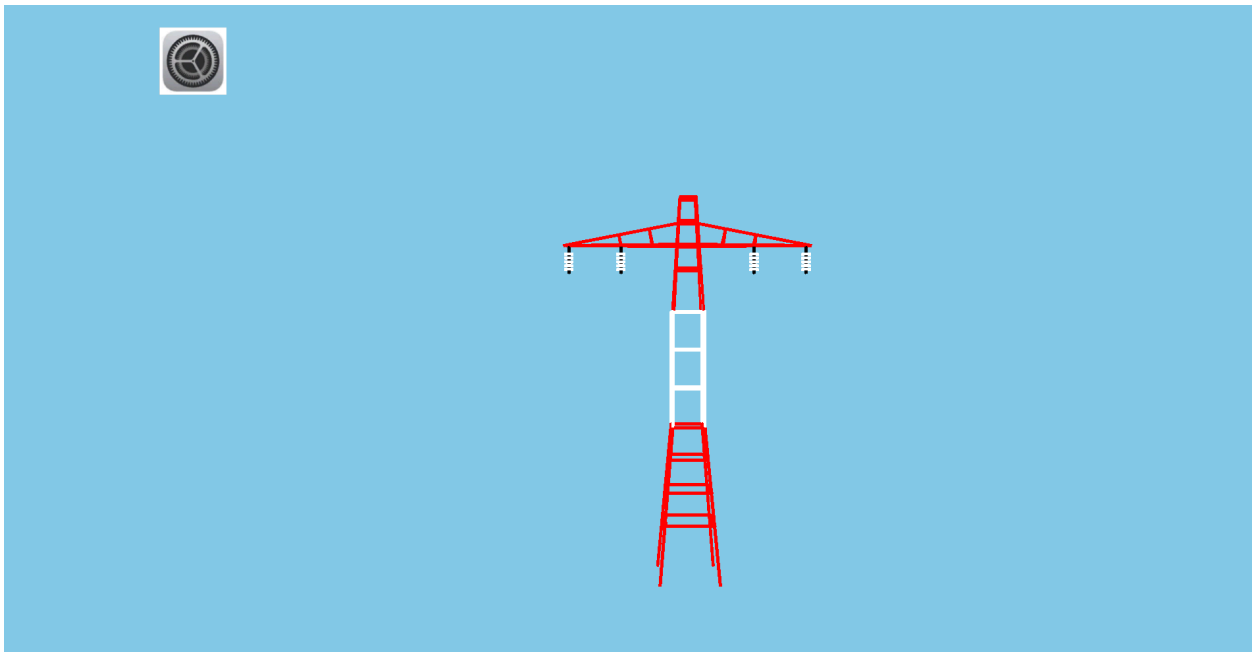

Fig. Transformer Object

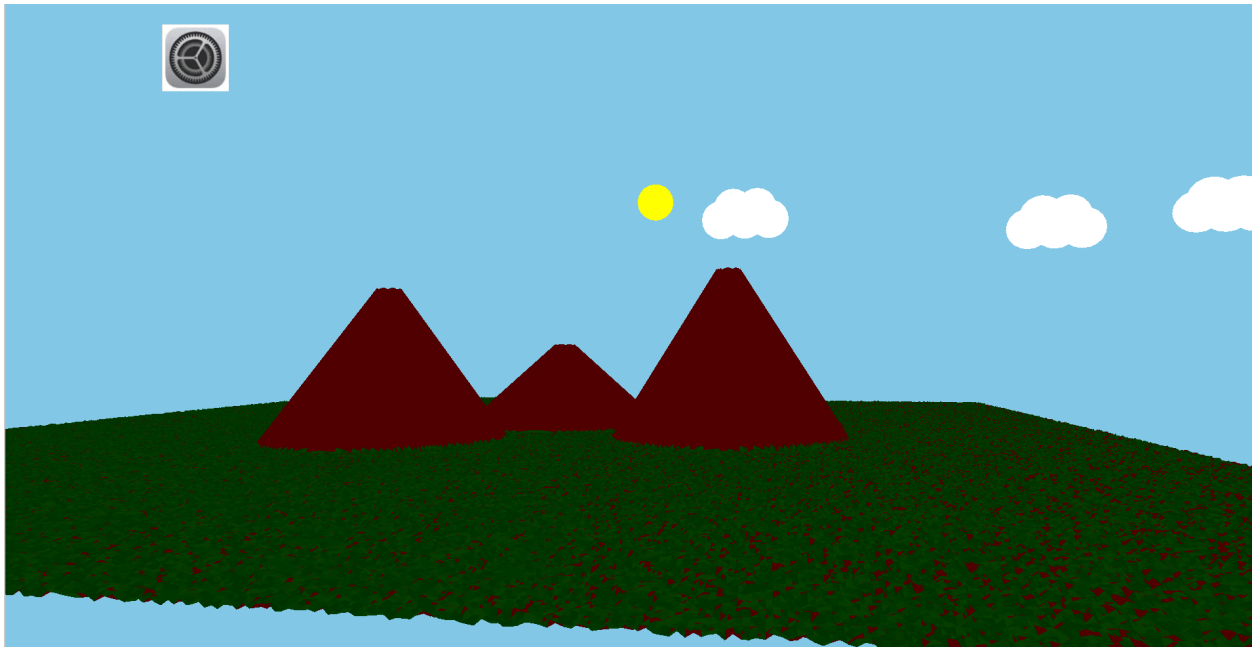

Fig. Background

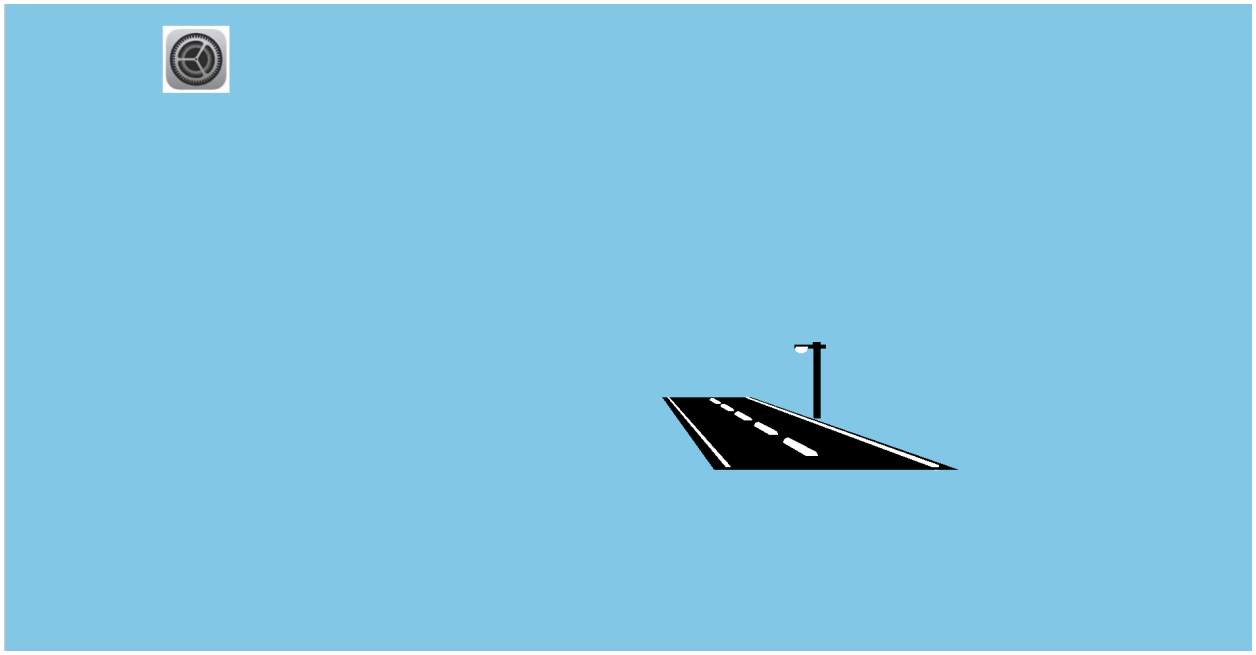

Fig. Road and Street Light

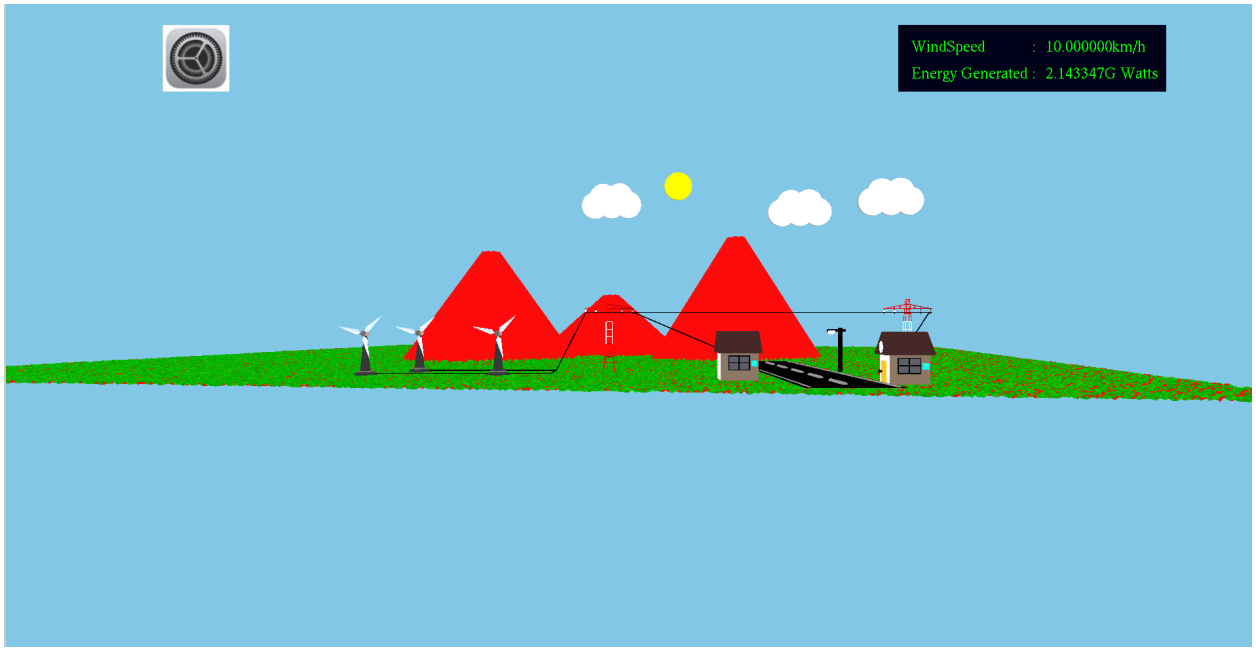

Fig. Zoom out

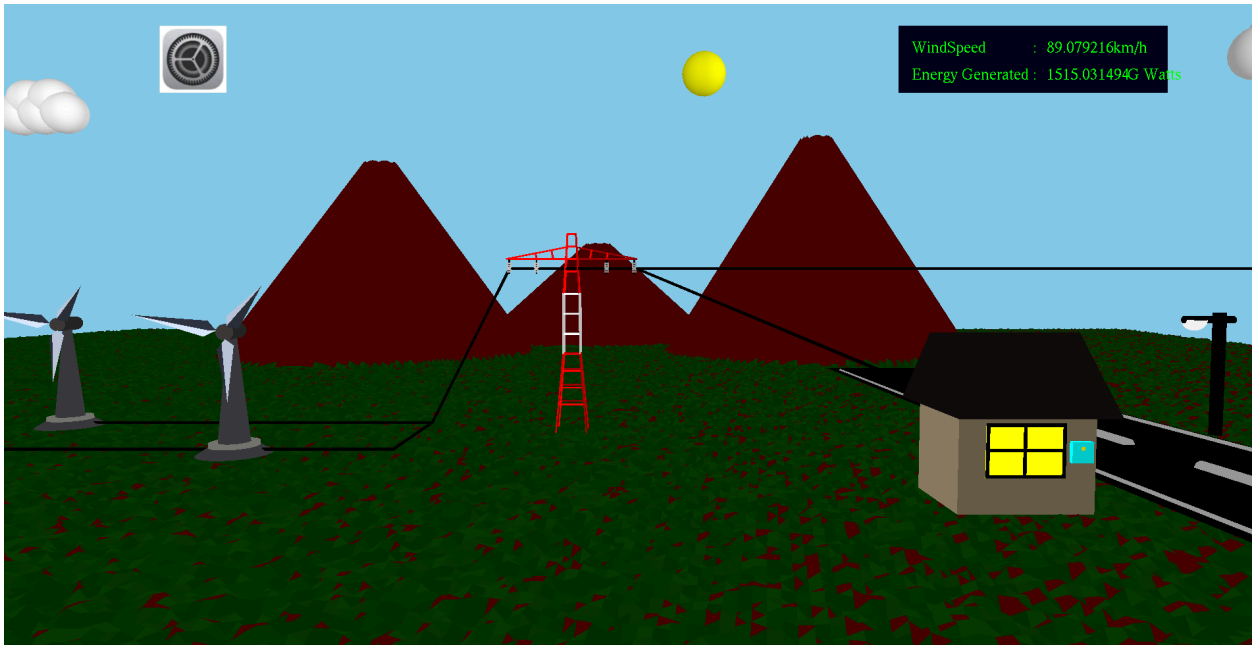

Fig. Zoom in

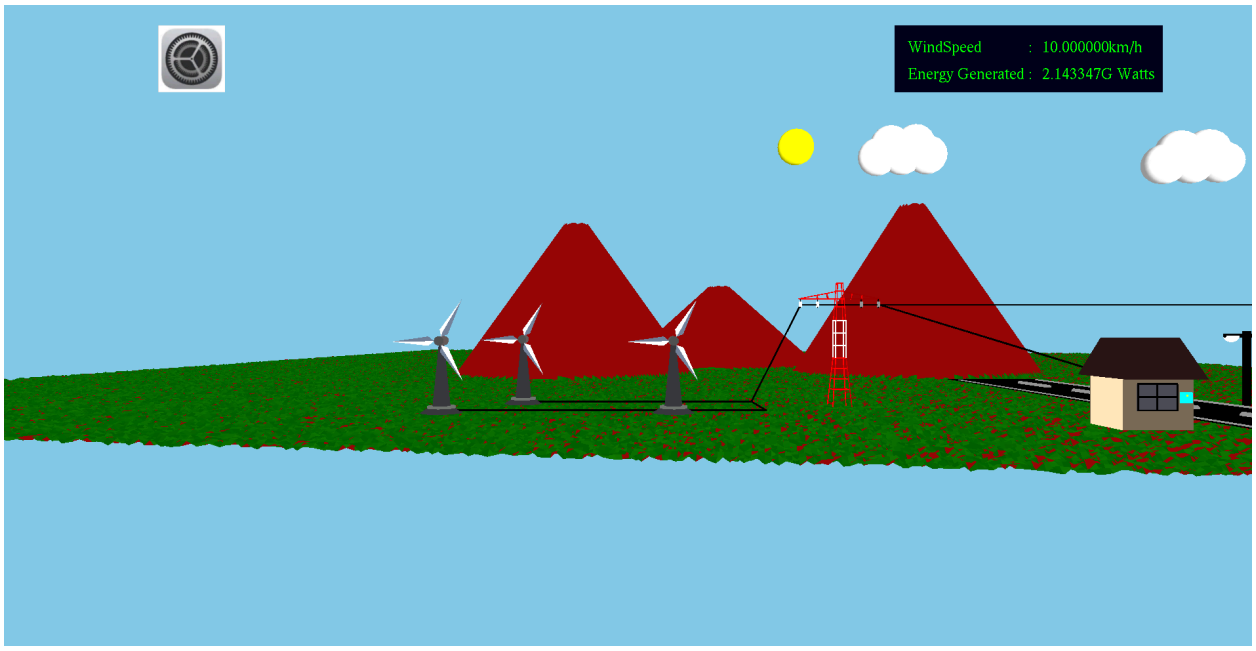

Fig. Translate window towards left

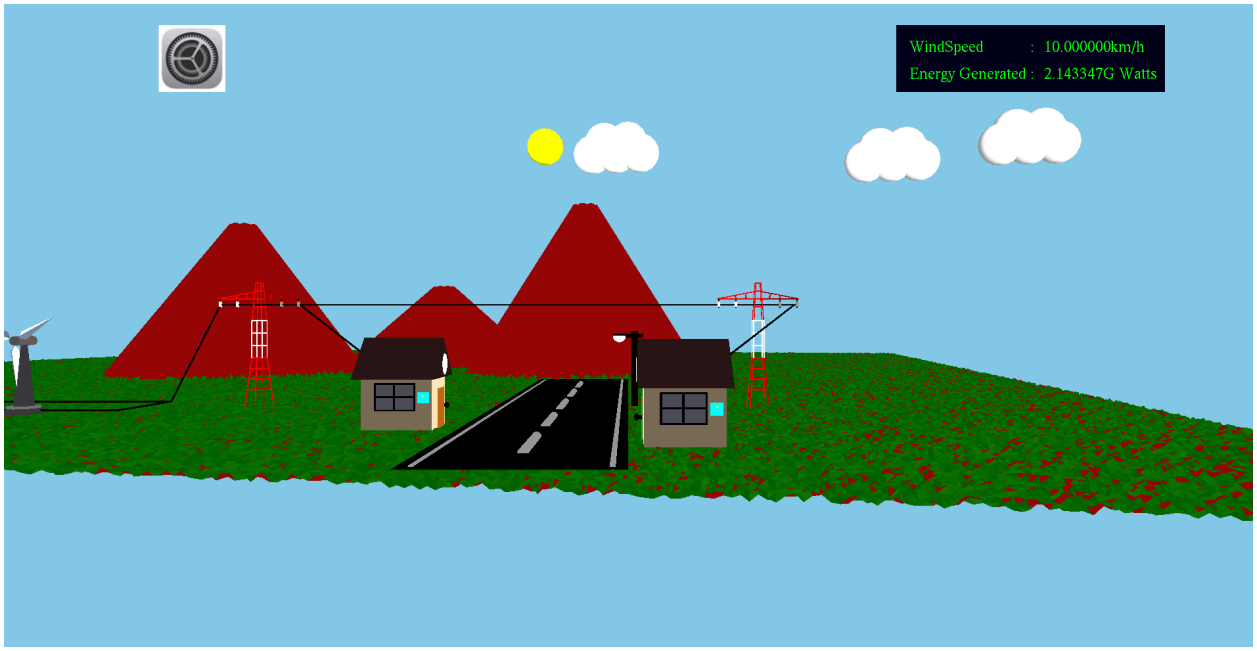

Fig. Translate window towards right

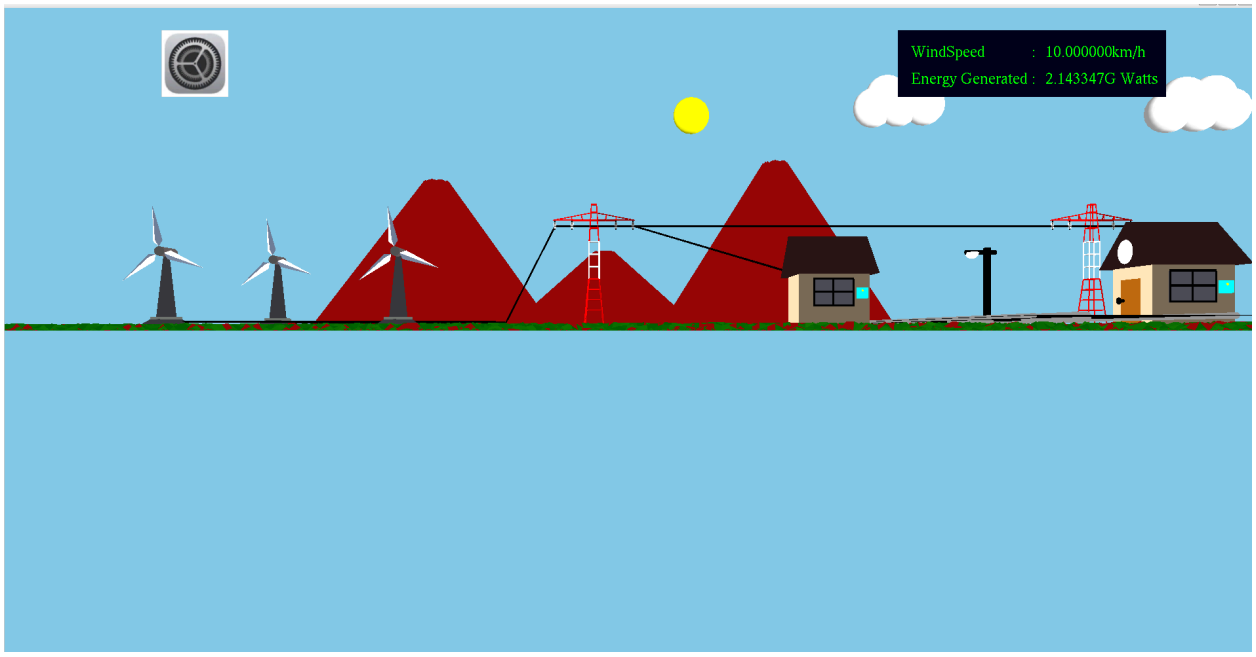

Fig. Translate window towards down

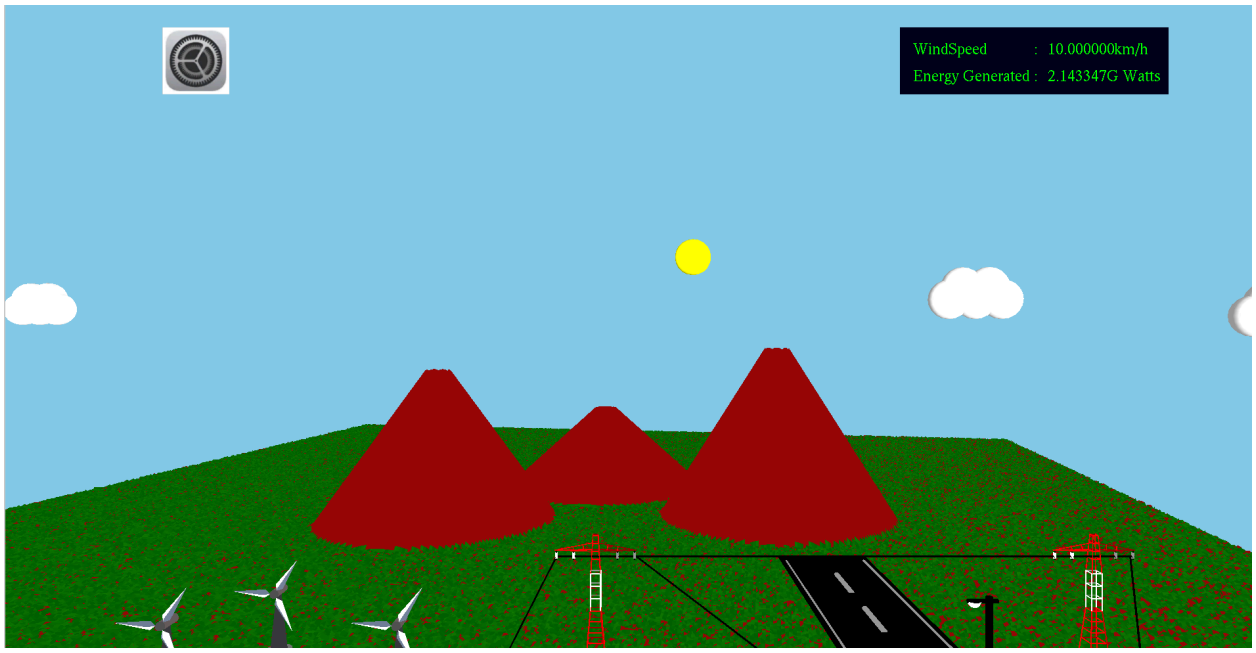

Fig. Translate window towards up

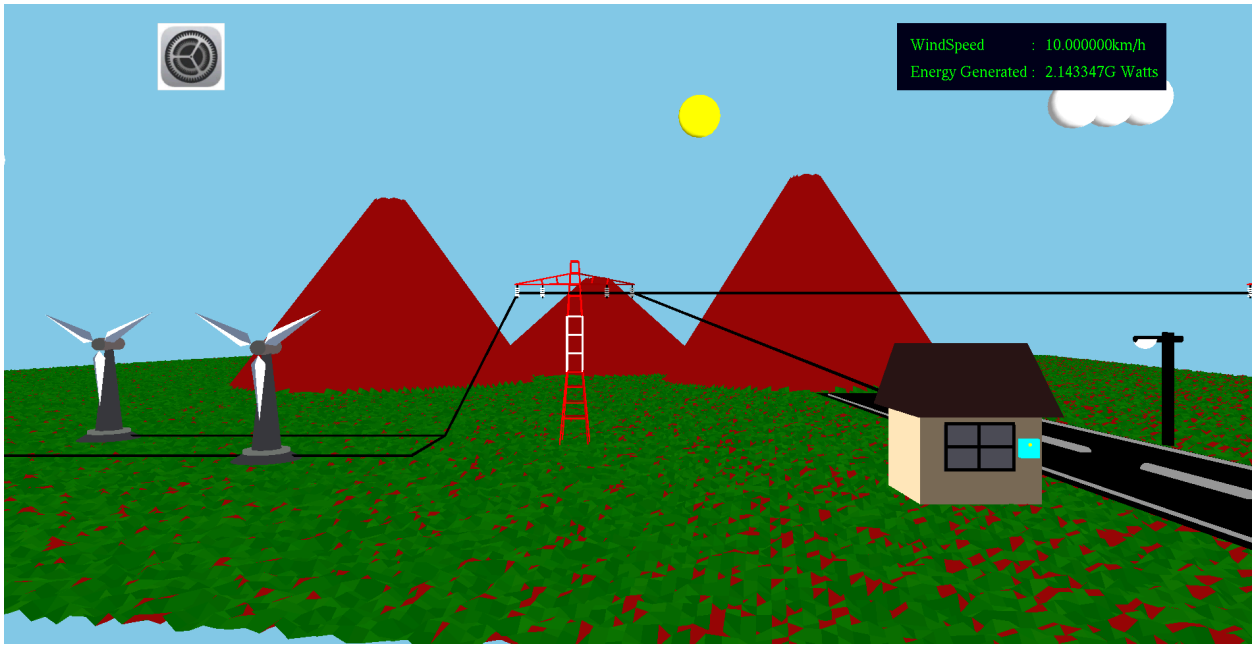

Fig. Translate window towards negative Z -axis

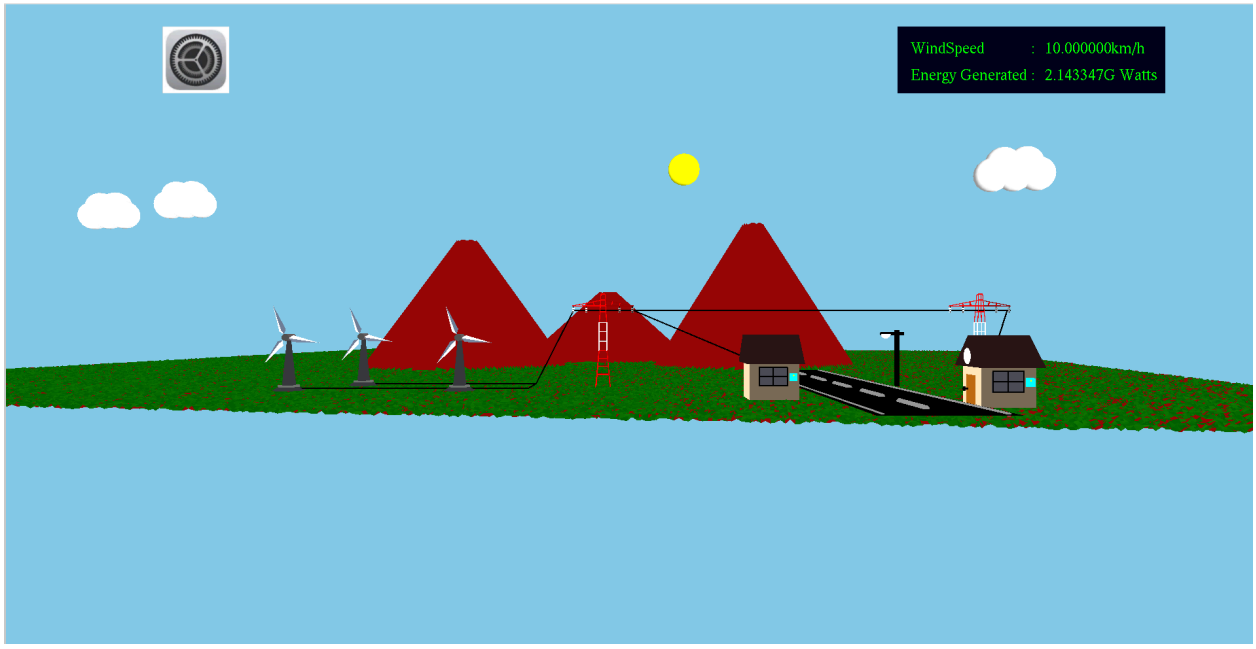

Fig. Translate window towards positive Z-axis

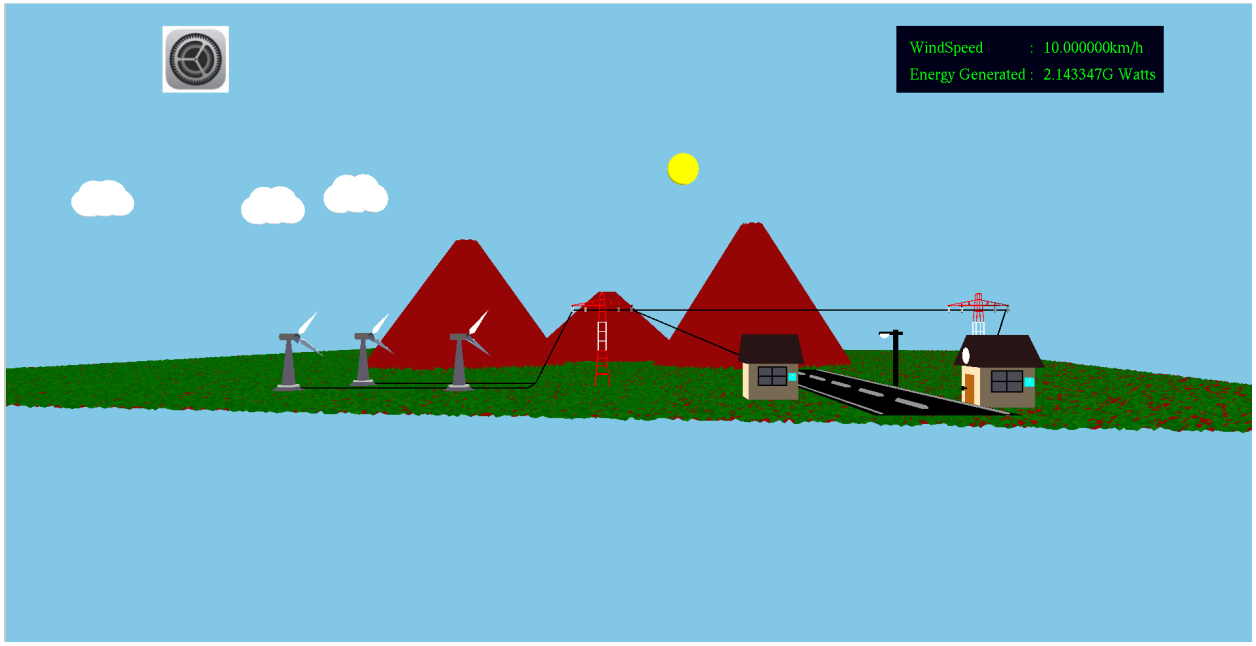

Fig. Rotation of head of windmill

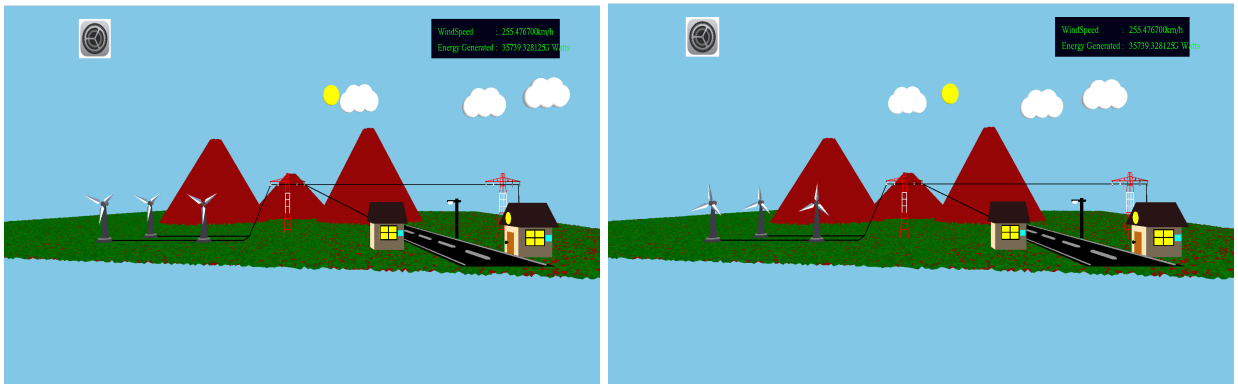

Fig. Wind direction change (left to right → right to left , see clouds for the change)

References

- https://github.com/cse200001043/Simulation-of-Windmill-Project