Microgrid Digital Twin

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Contents

Chapter. 1

Introduction

1.1 Background

The power grid has advanced into patches of difficult networks that interconnect public, local, and nearby frameworks, including in excess of 7,300 force plants, 160,000 miles of high-voltage and mid-voltage power transmission lines, and a large number of low voltage power circulation lines, all with changing conditions, age and limits, which have tangled the public network. This old-fashioned foundation is wasteful for power creation and conveyance, losing of almost about 5 Percent during the transportation. The failure in circulation adds to pointless non-renewable energy source consumption that adds more harmful gases into the atmosphere. Apart from this, the rise in electric power has increased so much in last few years that it becomes the need of an hour to have a technology which can help us to produce great amount of electricity in comparatively low prices.

1.1.1 Microgrid

A microgrid is a decentralized group of electrical sources, implemented using Digital Twins. This concept is critical as it is the core of the project and collecting a lot of information about the subject could ensure that the project goals are met in a timely fashion.

1.1.2 Digital Twin

As the name itself indicates the digital twin is a digital portrayal of any object, service or process. A digital twin can be a digital reproduction of an article in the actual world, for example, a stream motor or wind cultivates, or much bigger things like structures or even entire urban areas. As digital twin can be used to replicate the objects and services so it can go a long way in simulating the

actual working of the objects which further can be used to perform operations and model training in machine learning.

Chapter. 2

Methodology

2.1 Research Design & Data Analysis

2.2 Technical specifications

Hardware and Software used in the implementation of the digital twin of solar microgrid: The hardware which is mandatory for running this digital twin simulator is specification required for the system on which this simulation is running. The system needs to have:

- 8GB of RAM or Random-Access Memory
- At least 500GB of free storage should be there. SSD storage is preferable.
- High-resolution monitor with 1366x768 or greater
- Eight core Intel Xeon Processor
- Network Bandwidth greater than 1 GbE
- Ubuntu OS

More about Ubuntu: Ubuntu is Linux based free and open-source operating system which is gives us the best out of the box performance. Although the most widely used OS is Microsoft Windows but Ubuntu is utilized majorly by people with technical background. It has not so user-friendly user interface but the main reason behind its utilization is that it provides very fast processing of our program. Initially we faced difficulty in installing the Unity 3D on our Ubuntu system but afterwards by following some troubleshooting steps on the internet we were able to run this. We have used a C# script to read the CSV file which consists of the dataset which we used to design the digital twin of the solar microgrid system.

As this OS is majorly used by the people with technical background, it became easy for us to run the script without any hassle. Ubuntu came in market

by Cannonical which is treated as the parent company of this operating system. There are other developers too were involved when this operating system is being designed by the parent company. This company is only responsible for releasing the security updates on regular basis for the operating system ubuntu. Ubuntu name is taken from Nguni philosophy which means ubuntu is humanity to others. It seems to be correct as per the today's time as we used this IT infrastructure to develop a digital twin of such a great idea. This digital twin will definitely be proven as very useful simulation before the real-world implementation. Ubuntu also provides a great cloud support and is very favorable for running on Amazon AWS, Microsoft Azure and many more. As per the software part is concerned, we have used unity 3d to make all the visualizations and used it as a simulator in running our digital twin. Unity is considered as the game engine and was released in 2005 for Apple ecosystem by Unity Technologies. Later its support has been given to desktop, mobile, console and much more. This unity engine can be used for playing and designing games, but as far as the educational purpose is concerned, we have unity 3d for a three-dimensional simulation. We have constructed a digital twin and for visualizing the same, we have made use of Unity 3D software. More details about this topic have been discussed in the upcoming chapters.

2.3 Technologies Used

2.3.1 Micro Grid

Introduction

A microgrid is an independent energy framework that serves a discrete geographic impression, like a school and college campuses, emergency clinic complex, shopping complex, and many more. It can be defined as a limited-scale localized power station that has its own storage capacity and generation unites and defined boundaries. The aim of using microgrids is for the distributed, decentralized, and embedded energy production. Microgrids are normally upheld by generators or inexhaustible breeze and sunlight-based energy assets and are regularly used to give reinforcement force or supplement the main supply during the high demand times. These microgrids are programmed very carefully and are connected with each other by means of some complex programming and frameworks.

Background

In the same way as other innovations in the energy business, the concept of microgrid has been around in some form or other for a long time, but with some local name or name other than "microgrid", or with a similar degree of functionalities refinement and advancement that we see today. The concept of microgrid traces all the way back to the start of the electricity supply-business industry. In the year 1882, Thomas Edison opened his Pearl Street Station and

there he came to know that was no norm for an age dispersion framework for power, so designed a system for the distribution of electricity using the hit and trial approach and to the great surprise that system is having the majority of all the functionalities that we have in microgrid today.

The expression "microgrid" seems to have begun being utilized in the last part of the 1990's the point at which the US Department of Energy, in line with the US Congress, started a project that works on "How to maximize the energy distribution with least costing". Later on, several researches and refinements have been done in this field and now we come up with a very refined energy distribution system “microgrid”. That's not it, scientists are still working to make it more refine and advance.

How it works? Before directly jumping to the question "How microgrid works" we need to know how the grid works. The grid makes it possible to connect homes, organizations, and different structures to focal force sources, which permit us to utilize machines, warming/cooling frameworks, and hardware. Since all of these are interconnected, so whenever any part of the grid stopped working then the whole grid is needed to be repaired.

This is the place where the concept of microgrid comes into the picture. A microgrid by and large works while associated with the network, it can operate and break off by itself by making use of local energy in case of emergencies like thunder, power outage, storms, or any natural calamity and other related issues. A microgrid can be fueled by circulated generators, batteries, and additionally inexhaustible assets like sun-powered boards. The working of microgrid highly depends upon the question "how the requirements are managed and how the device is fuelled" In order to connect microgrid to grid, both are made to operate on same voltage level and a coupling is done between both to link them together.

Advantages –

1. The microgrid makes it possible to control and regulate the energy generated storage and power sources which can go a long way in controlling the power fluctuations in renewable sources of energy and thus improves the overall quality of the power generated.

2. Microgrids offer numerous monetary advantages. Accept sun-powered boards for instance. While they take from 7-20 years to pay for themselves, contingent upon state tax reductions or limits, they can save you a large amount every year once paid off. Sun-powered boards increase the value of your home and can be more financially stable than the energy created from petroleum products, which has not only high pricing but also a non-renewable source of energy.

3. Microgrids are additionally well known because of their dependability or reliability. Take the case when the electricity needs to cover a long distance before reaching the home or when the grid is at a long distance from the home in that case the chance of sudden occurrence of any natural calamity like storm, thunder is always a cause if concern that can affect the power

supply. Privately created energy doesn't need to go far, so a microgrid can give you power in any event, when outrageous climate takes out most electrical cables. On the off chance that your microgrid has differentiated and creates energy from numerous sources, for example, sun oriented and power modules, that adds one more degree of safety.

4. Microgrids are more modest, and can subsequently be introduced more rapidly than customary power plants. It is easy to incorporate the microgrids in the remote areas even without any power supply. Thus the microgrids makes it possible to satisfy the ever increasing power supply demand of this rapidly growing population.

Key Gaps –

1. Synchronization and coupling of the microgrid and grids can be hectic and creates an issue.
2. To ensure the long, proper and efficient working of the microgrid, it is needed to be fuelled up properly and all its requirements should be managed with high priority.
3. In order to store the electricity generated we will be needing some space resources because we will be needing some energy storage devices to store them.
4. Microgrid security is a deterrent remaining against the execution of microgrids.
5. Standby charge can also be a cause of concern.

Chapter. 3

Artefact Development Approach

3.1 Description of the Artefact development

3.2 Methodology

As in this project, we have created a 3D simulation of electricity generation from solar energy distributed and generated with the help of microgrid.

The whole project was divided into few modules as mentioned below –

3.2.1 How to convert solar energy to electrical energy

Basics about how solar panel works

1. When the daylight falls on the solar panels and it makes an electric field.
2. The power (electric field) so formed creates streams to the edge of the panel.
3. Since the electricity so formed is DC in nature so, it is made to pass to an inverter that converts it to AC, which further is supplied to the powerhouses and buildings.
4. Another wire moves the AC power from the inverter to the electric panel on the property (breaker box), which circulates the power all through the structure depending on the situation.

Advantages of Solar Energy and Solar Panels

1. Among all the advantages available for the solar panels the most important one is that it is the renewable source of energy, It is available everywhere in the world and in contrast with the other sources of energy the more we use it the better it will be for the environment. Solar energy will be open as long as we have the sun, subsequently daylight will be accessible to us

for at any rate 5 billion years when as indicated by researchers the sun will pass on.

2. Solar force is a pollution-free source of energy and most importantly it does not produce any ozone-depleting substance after its production.

3. It reduces the dependence and usage of non-renewable sources of energy like fossils fuels etc.

4. The inexhaustible clean force that is accessible all year long, even during cloudy days it produces some power.

5. The solar panels require significantly less maintenance. You just need to keep them moderately perfect, so cleaning a few times each year will do the work.

6. Solar energy can be utilized for different purposes. You can create power or heat. Solar energy can be utilized to create power in regions without admittance to the energy framework, to distil water in districts with restricted clean water supplies, and to control satellites in space. Solar energy can likewise be incorporated into the materials utilized for buildings.

Disadvantages of Solar Energy and Solar Panels

1. The solar energy is highly weather dependent, although solar energy can in any case be gathered during shady and blustery days, but the productivity of the solar framework drops by an significant amount. When Solar panels are subject to daylight they successfully accumulate good amount of solar energy. But during the cloudy, rainy day and in the night time it won't work with the proper efficiency for obvious reasons.

2. Although the maintenance cost of the solar panel is quite low but it requires a significant amount as the one time installation cost.

3. In order to generate more electricity we will be needing more solar panels and more panels means more space requirement. Thus it requires a large amount of space to generate a descent amount of electricity, so it is space expensive.

4. Despite the fact that contamination identified with solar energy frameworks is undeniably less contrasted with different wellsprings of energy, solar energy can be related to contamination. Transportation and establishment of solar frameworks have been related to the discharge of ozone-depleting substances.

Let's dive deep into the science behind the working of solar panels –

The solar panel is made up of lots of photovoltaic cells, where photovoltaic cells are the devices that convert the solar energy into electrical energy, These cells are made of semi-conductive materials, regularly silicon, a material that can lead power while keeping up the electrical unevenness expected to make an

electric field. Photons are rudimentary particles that convey solar radiation at a speed of 3 x 105 kms/sec. At the point when the photons strike a semiconductor material like silicon, they discharge the electrons from its particles, leaving behind an empty space. The wanderer electrons move around arbitrarily searching for another "opening" to fill.

To deliver an electric flow, be that as it may, the electrons need to stream in a similar way. This is accomplished utilizing two different types of silicon material. The silicon layer that is presented to the sun is doped with iotas of phosphorus, which has one more electron than silicon, while the other side is doped with boron particles, which have electron one less in number. The subsequent sandwich so formed works similarly to a battery: the layer that has more electrons turns into the adverse terminal (n) while the side that has a shortage of electrons turns into the positive terminal (p). An electric field is made at the intersection between the two layers.

At the point when the electrons are energized by the photons, they shifted to the n-side by an electric field, while the holes to the p-side. The electrons and holes are coordinated to the electrical contacts applied to the two sides prior to streaming to the outside circuit as electrical energy. This produces direct current. And in order to reduce the loss of photon during this process, a coating is applied on the top of the surface which is anti-reflective in nature and doesn't let photos move out of the panel surface.

Since the power so formed is DC in nature and as we know our all appliances works on AC, so solar inverter is there that convert the DC into AC.

A solar inverter is a sort of electrical converter which changes over the variable DC o/p into a utility recurrence AC which further can be provided to a business electrical lattice and powerhouses. It is a basic equilibrium of framework segments in a photovoltaic framework, permitting the utilization of standard AC-controlled hardware. Solar force inverters have exceptional capacities adjusted for use with photovoltaic clusters.

3.2.2 Energy Storage and Control System in Microgird

Energy Storage System in Microgrid

Energy Storage System is an innovation that stores power created from environmentally friendly power sources or from the pre-existing power grid with the aim of using it later when required. A microgrid is a discrete energy framework that gives the electric capacity to a particular area or office by coordinating with disseminated energy assets. Whenever there is an outrage in the primary grid then the microgrid directly switches into the island mode where the aim of the grid is to store more and more amount of energy in its storage resources. To store energy for sometime later, a microgrid proprietor needs an energy stockpiling framework. At the point when the principal utility can't supply power, a microgrid takes over consistently in the event that it has an energy storage system.

3.3 Energy Control and Management System in Microgrid

A microgrid is described by the appropriate integration of Storage, Consumption, and dissemination of energy resources with an aim to increase the self-sustainability of the power distribution grid's future. Such integration combination results in new difficulties to microgrid the executives that have never been presented to conventional force frameworks. So in order to solve this issue, there is the concept of intelligent microgrid management comes into the picture. The intelligent EMS takes care of few major thing like –

1. Forecasting the Energy requirements and activities

In this rapid world of advancement, the demand of energy is increasing at a very rapid speed and predicting the energy requirements and activities became the need of the hour. So in order to forecast the activities the Intelligent management system is pre-fed with machine learning algorithms which are backed by proper data and analysis, and these algorithms are used to forecast the energy requirements and activities, and on that basis proper arrangements can be made.

2. Optimization of Energy control and activities The different areas have different energy requirements, some may have high demand and some may have low. So it is very important to have proper energy control techniques that can bifurcate the areas on the basis of the energy requirement and on that basis it further control the supply. Also it should be capable enough to activate the storage system to store the surplus energy supply and switches between different modes when required.

3. Analysis of Energy Data

Data Analysis is an another import part of the intelligent management system, The microgrid have to work all the time and it will be generating lots of data about the electrical requirement and activities of different areas, so the data so formed can be use for analytical purposes and on that basis several insights can be formed which further can be used to derived patterns about the electrical requirements.

4. Human Machine Interface As human cannot understand the machine language and same as the case with machine, so there should be a simple and interactive user interface where the humans can interact and even a user with not much knowledge about technologies will be able to get proper insights from the system.

3.4 3D Visualization of the Modules

In order to have a better understanding about the working of different modules and to give a real-time touch to the system the concept of 3D visualization proves very helpful. There are few different modules available in the project and for them 3D visualizations are made using the unity 3D software.

1. Visualizing the solar panels

The visualization of the solar panels is made using the unity 3d software where it gives a complete information about where the solar panels are placed and at what angles the panels are installed.

As shown in this image, the solar panels are install on the ground and is it different for different buildings where multi-color the bar graph in the top right corner give the units of electricity produced by the solar panel. For the building 1 there are 6 panels available, for the building 2 we have 12 panels available and for the building 3 we have 18 panels available.

2. Visualizing the Buildings

There are different buildings available and different simulations have been made for each building. These kind of virtualizations give a more clear description about the real-time view of the interacting system.

3. Visualizing the Battery

A battery is a power source comprising of at least one cell whose compound responses make a progression of electrons in a circuit. They by and large involve three distinct parts for example Anode, Cathode, an electrolyte that makes the current pass. At the point when a battery is providing electric force, its positive terminal is the cathode and its adverse terminal is the anode. The terminal checked negative is the wellspring of electrons that will course through an outer electric circuit to the positive terminal. At the point when a battery is associated with an outer electric burden, a redox reaction took place that converts the high-energy reactants to low-energy products, and the free-energy contrast is delivered to the outside circuit as electrical energy.

4. Visualization of the Generator

An electric generator is a machine that converts the mechanical energy over to electrical energy which further is transmitted and dispersed over electrical cables to business, homegrown, and modern clients. The mechanical power required to generate the electricity is normally acquired from a pivoting shaft and is equivalent to the shaft force increased by the rotational, or rakish, speed. The electric generator's mechanical energy is normally given by gas, wind, steam turbines. Electrical generators give virtually all the force that is needed for electric force networks. When the generator is in operation, it creates up to 24000Volts of current. the power that is generated is a type of alternating current, which is charged to the voltage required and changed to coordinate current communicated over transmission lines as direct current, and afterward modified back to AC at the place where it is supposed to be used.

5. Microgrid Components

6. Load Demand The major segments of the microgrid comprise load management and load control. It is always required to keep an equilibrium between power demand and supply. Microgrid control frameworks need to continually check the requirement and load and take required actions to balance it. The load requirement can be different for single or multiple clients or devices as per their requirements.

7. Substation

A substation plays a major role as a vital hub in the power system organization and a junction for power trade. It is the framework liable for transmission and dissemination between transmission frameworks and power generations. Substations get voltage from the force plants by high-voltage lines. Voltages are changed in accordance with necessities and dispersed to clients.

Chapter. 4

Empirical Evaluation

There are majorly two types of evaluation of any system namely qualitative and quantitative Both of the evaluations we will be going to cover in detail in this chapter. Qualitative Analysis: In this analysis, we will be observing the more on the quality part of our digital twin model. In a random survey and feedbacks from the subject experts, it has been observed that electricity is something which is the need of the hour and there should be some sustainable source from which we get electricity. As we talk about sustainable energy source, we get opinions of having electricity from the windmill, hydroelectricity and solar electricity but when we talk about the more feasible and most economic electricity production then the best comes out to be solar energy. After getting this idea, we thought of having a simulation or proof of concept kind of thing but then we came to know that what else can be better than the digital twin of solar microgrid. Now as we researched further, we found results on digital twin to be implemented in many areas and there are many interests for solar microgrid as well, but there has been no significant try to merge both of these concepts. In this thesis, we merged both the things i.e., solar energy from the microgrid and the digital twin. We have tried to implement the digital twin of the solar microgrid which will help us to analyze that the assumed system of installing a solar microgrid in the campus of Deakin is considerable or not. The results turned out to be great and the same is discussed in the quantitative analysis of the digital twin of solar microgrid. We have also prepared a set of questions about the need of solar microgrid and collected the review of people who holds an expert knowledge in energy subject and also on the people who have no knowledge about solar microgrid, the results seem to be interesting.

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Figure 4.1: Bar Graph on People Opinion vs Percentage of People

Quantitative Analysis: In this analysis we look at the results given by our

digital twin of solar microgrid. We have installed the solar panels on the top of three building and according to our observation, building 3 is the greatest producer of the electricity among the three buildings. The reason behind the greatest producer is big surface area. As far as solar power is concerned it is directly proportional to the surface area exposed and the projection of sunlight falling on that region. If we observe, then building 1 and building 2 are of similar sizes, still building 2 has produced more electricity than the building 1. The reason which is observed here is the amount of sunlight the buildings are getting. The more clarity can be drawn from the below table:

In total of 34 days of reading of total electricity from building 1 is 143,826; building 2 is 279,652; and that of building 3 is 431,520.

Table 4.1: Amount of Sunlight on Specific building and day

	Building 1	Building 2	Building 3
Day 1	3769	7538	11307
Day 2	3693	7386	11079
Day 3	4540	9080	13621
Day 4	3022	6045	9068
Day 5	3572	7145	10718
Day 6	4431	8862	13293
Day 7	4341	8683	13025
Day 8	4677	9355	14033
Day 9	4920	9841	14762
Day 10	4640	9281	13922
Day 11	5251	10502	15753
Day 12	4712	9425	14138
Day 13	4046	8093	12139
Day 14	5801	11602	17403
Day 15	4564	9131	13697
Day 16	4152	8305	12457
Day 17	3440	6861	10322
Day 18	3426	6853	10279
Day 19	4246	8432	12739
Day 20	4341	8683	13025
Day 21	4884	9769	14654
Day 22	4592	9184	13776
Day 23	3866	7732	11598
Day 24	4831	9663	14495
Day 25	5012	10024	15037
Day 26	4901	9802	14704
Day 27	3807	7615	11423
Day 28	3075	6151	9227
Day 29	3227	6455	9683
Day 30	5027	10054	15081
Day 31	4183	8366	12550
Day 32	3914	7828	11742
Day 33	3559	7119	10679
Day 34	3363	6727	10091