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Article

Study of Using Virtual Reality Technology to Simulate the Generation of Electrical Power from Different Sources

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Abstract:

Virtual reality (VR) is one of the most common technologies nowadays, which make a virtual environment exactly similar to the real environment. The purpose behind this is to test several issues (designing or manufacturing), this lead to reduce the cost and risk especially in the mass manufacturing sector. VR involved two basic conditions, the hardware part which represented by glasses, cameras, sensors and computers, while the software part is represented by the cods and program language. This technology is used here to test and simulate the process of generating electrical energy from several sources. The power sources were divided into two parts; the basic sources that generate large amounts of electrical power that cannot be dispensed with, such as hydroelectric stations that depend on waterfalls, thermal stations that depend on various types of fuels, as well as nuclear stations that depend on special radioactive fuel. The variables of each main source that directly affect the process of generating electrical power were identified, and each of these variables was given a specific symbol when writing the VR program. But, at present, this research is only to link VR technology to the process of generating electrical power. While, the second part of sources are secondary or auxiliary sources, which cannot be fully dependent upon to suffice with generating electrical power (solar and wind energy which were discussed briefly). In order to achieve the main purpose of using VR technology, we assumed a certain cost for establishing a hydroelectric power station. With a simple calculation process, it can be proven that this technology can reduce the cost of establishing the station to a third of the expected value after eliminating the need for design and installation, this may be repeated two, three or four times (if VR technology is not used), which means moving the equipment and replacing it two, three or four times. Therefore, the directly appropriate selection of this equipment will reduce the cost to a third (perhaps a half or a quarter depending on the repetition times).

Keywords:

Hydroelectric Stations; Nuclear Stations; Power Sources; Simulation; Virtual Reality (VR).

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Highlights:

- Virtual reality technology transports the user to test some activities in a virtual world.
- The process of generating energy from different sources can be supported using VR.
- VR reduces cost and risk when using technology in the mass manufacturing sector.
- VR involves two basic requirements, hardware and software.

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1.INTRODUCTION

Virtual reality (VR) technology is one of the modern technologies, it is a computer technology that provides a three-dimensional environment that surrounds the user and responds to his actions in a natural way [1-3]. This technology based completely on sensor technologies which have made daily life better for people. The design of the response is based on the data collected by sensors, which are tools used to detect changes in the source or surroundings [4]. VR can provide hands-on learning experiences without the risks or costs associated with physical training. Through it, products can be designed and manufactured in a way that ensures many safety factors in addition to not worrying about costs [5,6]. Virtual Reality may have been started practically through video games, when the user feel that he involved truly in the environment of the game, but it is worthy to be mentioned that this technology is expanded later to include many different fields. It can be used in the health sector to do virtual surgery or in the military sector for virtual training...etc. In other words, virtual reality technology is now included in most life applications [7-9]. In fact, any manufacturer should commit to using this technology. For example, car factories must test their cars before sending them onto the street, as must aircraft factories, and any other factory that produces such important and complex products [10-12]. In this research we will discuss how to engage this technology (VR) with the electricity power sources (the basic and auxiliary sources). The basic electrical power sources will be discussed in details, through calculate all their parameters. While the auxiliary or secondary power sources will be taken in brief. The first electrical power source is the hydroelectric plants, and this type of plants depends completely on the dams which are established near by lakes [13]. These hydroelectric stations depend on several factors to perform their work, namely the rate of water discharge, the depth of the dam, and the efficiency of the equipment [14-16]. The second electrical power source is the thermal power plants, which can use all burning fuel types such as gas, diesel or other oil products [17,18], They rely on the same mathematical model to calculate the amount of fuel input and the amount of electrical energy produced [19,20]. Lastly, the third basic power source is the nuclear power plant, and this type of stations can generate huge amount of electrical power by using the radiation materials such as Uranium and Thorium [21,22]. While auxiliary or secondary electrical energy sources are sources that cannot provide sufficient electrical energy at the present time, which is known as sustainable or renewable energy [23]. Sun and wind are the best example of clean energy obtained to produce electrical energy [24,25]. So these kinds of power sources will be discussed briefly in this research.

2.HYPOTHESIS OF VR FOR GENERATING THE ELECTRICAL POWER

In this section of the paper, the virtual reality hypothesis will be explained by representing the parameters of each energy source as parameters in the chosen computer program language. Hence, any change in these parameters in the program codes leads to a change in the production of electrical energy in the power source (station). The primary energy sources that are used in large quantities will be studied in detail, while the other auxiliary sources that are considered secondary at the present time will be discussed briefly.

2.1.Hypothesis of VR for Hydroelectric Station

In hydroelectric stations, the principle of generating electrical power is depending on water falling in huge amount from a height level. Different types of turbine are used in these stations according to the head of dam which allow the water to discharge or fall from it. Propeller turbine is used for such low head of dam which about 30 meters, while Francis turbine is used for higher than the previous type till about 200 meters. But when the head level of dam is so high, Pelton turbine is preferred to be used then. Next Figs. 1-5 show the three levels of height (low head, medium head and high head).

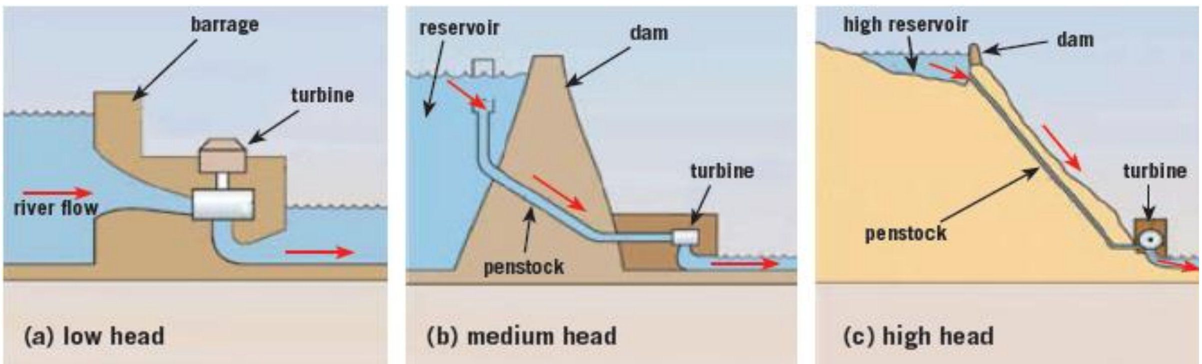

Fig.1 Types of Hydroelectric Head Levels.

After designing this type of station (hydroelectric station) in terms of size, shape and other basic parts; or even by choosing a suitable design from a previous station which is already exist before to develop it for example, the next step will be determine all the parameters that affect directly on the amount of produced power in this station.

$$\textbf{Power in (watt)}, (p) = \frac{work}{time} \quad \textbf{(1)}$$

$$work = weight * distance \quad \textbf{(2)}$$

So, this lead to: $power = \frac{weigh * distance}{time}$

$$weight = mass * 9.8 \quad \textbf{(3)}$$

This means:

$$power = \frac{mass * 9.81 * distance}{time} \quad \textbf{(4)}$$

If we rewrite the equation in terms of units, it will be as follow:

$power\ (watt) = 9.81 * \frac{kg * m}{sec}$, then multiplying this formula by $\frac{m^3}{m^3}$ to obtain a specific known model, this yield:

$$power\ (watt) = 9.81 * \frac{kg}{m^3} * \frac{m^3}{sec} * m$$

In order to build a good model, we are going to simplify all the terms in the last formula one by one. As long the density of water is 1000 for each 1 kg per cubic meter, so we can replace the term $(\frac{kg}{m^3})$ by 1000 as the quantity of the density; and in the same way we can replace the other term $(\frac{m^3}{sec})$ as the discharge water which will denoted by Q. While the last term (m) refer to the height of the dam which will denoted by h. So, we can rearrange the formula as follow:

$$power\ (watt) = 9.81 * 1000 * Q * h \quad \textbf{(5)}$$

But, we still can simplify the formula by dividing each side on 1000, which means the power in left side will be measured in k watt. Lastly, another term will be added to the right side which called the efficiency of all over the plant (ƞ) because there is always some loss in the produced power. By taking a look to the final mathematical model of the hydroelectric station, it can be observed that the power there depends on several parameters:

$$\textbf{P(kW) = 9.81 (Q) (h) (ƞ)} \quad \textbf{(6)}$$

P(kW): the power in k watt
Q: the discharge of water
h: the height of water above the earth
ƞ: the efficiency of the station

Now, we can give each parameter of the previous last equation a certain symbol, and let be as follow:
P(kW) = X1, (X2, X3, ... etc. will be the symbols of power for other sources)
Q = dw, which denote to the quantity of discharge water
h = dm, which denote to the dam height
ƞ = e1, which denote to the efficiency and will be represented by a limited numerical value (from 0 to 1)

Then after determining the symbols of parameters that will be involved in the suitable program language (will be explained later in this paper), we will obtain the best possibility result to produced the power, as well as decrease the cost and risks.

2.2.Hypothesis of VR for Thermal Electric Station

In thermal electric stations, the principle of generating electrical power is depending on burning the fuel, whatever its type (gas, diesel or other oil products). The stations in this type of electrical source are built in specific mainly elements; the first of all is the combustion chamber (or the boiler in steam power station), this element is responsible to convert the burning operation (or boiling water in steam stations) to heat energy; the second main element is the turbine which is responsible to convert heat energy to mechanical energy; while the most important third element is the generator which is responsible to convert mechanical energy to demand electrical energy.

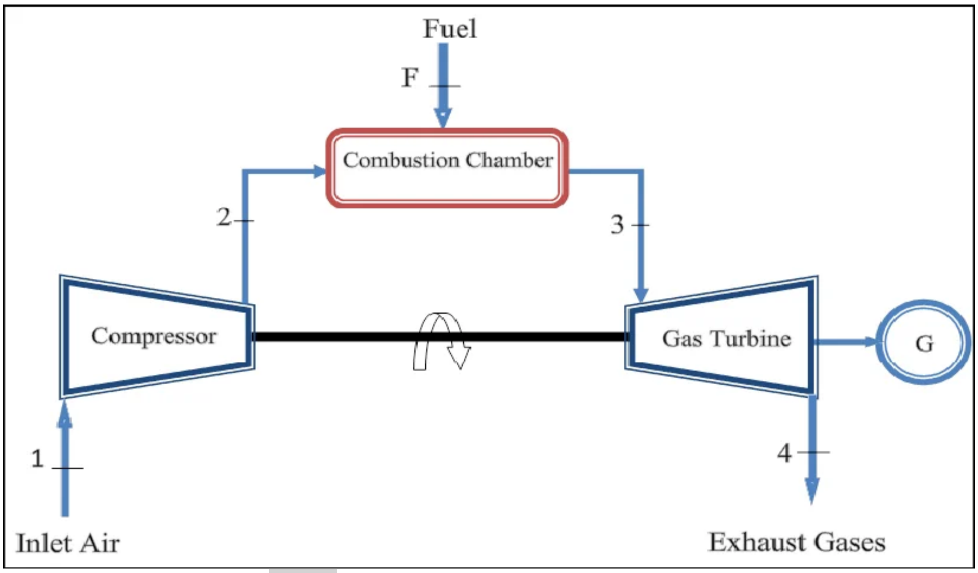

Fig.2 Thermal (Gas) Electric Station.

After designing this type of station (thermal station) in terms of size, shape and other basic parts; or even by choosing a suitable design from a previous station which is already exist before to develop it for example, the next step will be determine the amount of demand fuel in order to produce each kWh of electrical power. And the procedure will be done through determining the overall efficiency of turbine, generator and other main elements of the station.

$$\eta = \frac{O/P}{I/P} \quad \textbf{(7)}$$

η: is the overall efficiency of the station, which is the result of multiplying the efficiency of each main element and it takes a value from 0 to 1

O/P: is the requested output power which is measured in kWh

I/P: is the input power which refers to amount of burned fuel

As we mentioned above that output power will be measured in kWh, so for each 1 kWh of produced electrical power (which represent 860 k. calorific/kWh) we can calculate the amount of fuel that needed to be burned. Thus, we can find the fuel by unit k. calorific/kg, where this unit (calorific) is the amount of heat that required raising the temperature one gram of water one centigrade degree (°C).

Now, we can give each parameter of the previous last equation a certain symbol, and let be as follow:

η = e2, which denote to the overall efficiency of the thermal station, and will be represented by a limited numerical value (from 0 to 1)

O/P(kWh) = X2 (let X2 = 1 kWh, as a standard output to know the required input of fuel)

I/P(kWh) = X'2, which denote to the amount of fuel

Moreover, by involving these symbols of parameters in the suitable cods of program language of VR, we will obtain the best value of fuel burned to produce the power, as well as decrease the cost and risks.

2.3.Hypothesis of VR for Nuclear Power Station

In nuclear power stations, the principle of generating electrical power is depending on operation of fission the nuclear fuel (Uranium U235 or Thorium Th232 ...etc.) in a special apparatus known as a reactor. The heat energy that released is utilized in raising steam at high temperature and pressure, this lead to run the turbine which converts steam energy into mechanical energy; then the turbine drives the alternator which converts mechanical energy into electrical energy. The most important feature of a nuclear power station is that huge amount of electrical power can be produced from a relatively small amount of nuclear fuel as compared to other conventional types of power stations. It has been found that complete fission of 1 kg of Uranium (U235) can produce as much energy as can be produced by the burning of 4500 tons of high grad coal.

Fig.3 Nuclear Power Station [22].

After designing this type of station (nuclear reactor) in terms of size, shape and other basic parts; or even by choosing a suitable design from a previous reactor which is already exist before to develop it for example, the next step will be determine all the parameters that affect directly on the amount of produced power in this station and to determine the amount of demand fuel.

$$\textbf{Power in (watt), } (\boldsymbol{p}) = \frac{\boldsymbol{No.of\ atoms}}{\boldsymbol{No.of\ fissions}} \quad \textbf{(8)}$$

Number of atoms in 1 gram of Uranium

$$(\boldsymbol{U235}) = \frac{\boldsymbol{Avogadro\ no.}}{\boldsymbol{mass\ no.}} \quad \textbf{(9)}$$

The constant value of Avogadro number is = $6.023 * 10^{23}$

And assuming to use the Uranium that its mass number is = 235

Thus, the result always = $2.563 * 10^{21}$
As shown in the equation above, this result is happened when the Uranium fuel is 1 gram only. But, it should multiply the result by the total grams of fuel that used in the reactor. It means, the numerator of the original nuclear power equation is always equal to $2.563 * 10^{21}$ multiply by the total grams of Uranium (U235). So, the first parameter that could affect the produced power is the quantity of nuclear fuel, or in a simply words the total grams of Uranium. This (total grams) will be denoted by tg as a changeable parameter in the VR program later. Now, when we take a look at the denominator of the original equation of nuclear power, we'll find that the number of fission required for 1 watt-second in Uranium (U235) = $3.1 * 10^{10}$. And, this value is constant unless multiply by the period of time of fission operation. So, the second parameter that could affect the produced power is the period of time of fission. This (period of fission) will be denoted by pf as a changeable parameter in the VR program later. Lastly, from the previous explanation about nuclear parameters that affect the amount of produced power, we can put the last equation in the following general form:
Power in (watt),

$$(p) = \frac{No.of\ atoms * total\ grams}{No.of\ fissions * period\ of\ fission} \qquad \textbf{(10)}$$

Now, we can give each parameter of the previous last equation a certain symbol, and let be as follow:
P = X3, (mostly will be a huge amount of power)
No. of atoms = No.a = constant value = $2.563 * 10^{21}$
Total grams = tg,
No. of fissions = No.f = constant value = $3.1 * 10^{10}$
Period of fissions = pf
Then, all these symbols of parameters will be included in the suitable cods of program language of VR, in order to obtain the best value of produced power and the required fuel, as well as decrease the cost and risks.

2.4.Hypothesis of VR for Other Auxiliary Sources of Electrical Power

As we mentioned in the introduction, auxiliary or secondary electrical energy sources are sources that cannot provide sufficient electrical energy for cities and large factories independently at the present time, such as energy obtained through the sun (solar energy) and wind, these types of power source will be discussed in brief. Solar power systems take sunlight energy and convert it into electricity, the panels used for this are referred to as photovoltaic panels. Solar photovoltaic systems use sunlight to generate electricity for domestic and commercial use. These systems are able to store excess electricity in batteries for later use or feed the stored energy into the electricity grid. From previous lines, it's clear that the three basic elements of solar energy are solar cells, inverters and batteries.

Fig.4 Elements of Solar Energy.

So taking each one of these elements and discovering the parameters that could affects the amount of power, we can build up our program in the virtual reality. For example, if we talk about the first element (solar cells), we can consider that the numbers of cells as well as the solar oriented angle are the most parameters which affect the produced power. So we can give them specific symbols referring to these parameters in the cods of virtual reality program. In the same manner we can redandan the procedure with the other two elements of solar energy (inverters and batteries). Moreover, same manner can be applied with each other power sources such as wind source.

3.STUDY OF VR PROGRAMING AND PROCEDURE

3.1.Hardware and Tools Needed for VR

Virtual reality hardware includes virtual reality glasses, mobile devices, sensors, cameras and headphones that allow the user to hear high-quality sounds and sound effects that increase the sense of realism and interaction in the virtual environment. The experimental stage of this study starts with a portable camera which can move with 360 degree, the camera has to be put in a point up the smart helmet that is worn by a person who does the experience. Next figure show an old version of such smart helmet that we talked about here:

Fig. 5 Smart Helmet.

The helmet is connected to a hand-free tablet, or other wearable computer, and the footage recorded by the camera is broadcast live to customers who may be in more than one location. On the other side of the broadcast, the virtual reality VR glasses worn by customers allow them to inspect and verify systems while carrying out on-site tests, in a unique experience that takes them directly to the site of the event.

3.2.Software and Programming Necessary for VR

It can be implemented by several languages, but the 5 most important programming languages for this technology (virtual reality) are:

First: C# language, it is difficult to program virtual reality for a complex process such as the process of generating electrical power using this programming language because it is used for beginners and for educational purposes in general.

Second: C++, this programming language is considered suitable for complex applications, but it requires highly qualified programmers, which makes it difficult to use and develop by ordinary users.

Third: Java (JAVA), which is considered a multi-use programming language, especially in the field of image enlargement.

Fourth: JavaScript, which is an easy programming language that allows easy communication in applications that are less complex than the subject of electrical power plants.

Fifth: Python. This programming language can be considered the most suitable language that meets the needs of the many variables (parameters) in the program as well as being easy to understand and develop by users.

By choosing the python programming language to build virtual reality in the first electrical power generation source in our research, which is the hydroelectric power station, we will take the parameters that were identified in the previous paragraphs (hypothesis of VR for hydroelectric station):

P(kW) = X1
Q = dw
h = dm
ɳ = e1

Then, these parameters are involved in the python program, and observe any change in the amount of produced power in case of changing the values of these parameters.

Using same procedure with the second generation source in the research here again (thermal electrical station):

ɳ = e2
O/P(kWh) = X2
I/P(kWh) = X'2

And, by involving these parameters in other programming language of VR, the result and the efficiency of the power plant will be very clear to be observed.

Lastly, with the third power source which we set its parameters in this research (nuclear power station), as follow:

P = X3
No.a = constant value = $2.563 * 10^{21}$
Total grams = tg,
No.f = constant value = $3.1 * 10^{10}$
Period of fissions = pf

These parameters also are involved in an independent other VR program in order to determine the power station ability of producing the electrical power.

4.HOW VR TECHNOLOGY AFFECTS COST REDUCTION

If we assume the necessity of establishing a hydroelectric station to generate electrical energy, the process of choosing the appropriate turbine for the height of the dam and the flow rate of water will be the most important part of the construction of the station. But, if the turbine is chosen in the traditional way, which is without using VR technology, the possibility of error will be very large, and so on for the rest of the other parts of the station. As for the use of virtual reality, whose small cost can be neglected compared to the high costs of such giant strategic projects, there will be no need to test more than one turbine, and there will be no need to redesign and move more than once, or re-install them, etc. for all parts of the station so that all components are ready to work as soon as they are installed, and have already been tested virtually and with almost real simulations. Suppose we will need to test the installation of a turbine in a hydroelectric station without using VR technology. We will probably have to check the turbine type three or more times, which means three processes of design, transportation and installation. Thus, the process of building the station will decrease to one-third of the cost. This applies to the rest of the large parts of the station (penstock of water, generator, and transformer), so the cost of constructing the station will decrease by approximately one-third. Below is a table showing the most important parts of establishing a hydroelectric station, along with its proposed price and the percentage of cost reduction after simulating it with VR technology. The expected percentages in the previous table to reduce the cost of establishing a hydroelectric station can be represented by the following diagram, which shows the difference in the cost of construction using VR technology and not using it.

Table 1 The Percentage of Reducing the Cost of Construction of a Hydroelectric Station.

Most important parts of hydroelectric stations	Without VR technology			With VR technology		
	design	transportation	installation	design	transportation	installation
Turbine	Unit price	Unit price	Unit price	1/3 Unit price	1/3 Unit price	1/3 Unit price
Penstock of water	Unit price	Unit price	Unit price	1/3 Unit price	1/3 Unit price	1/3 Unit price
Generator	Unit price	Unit price	Unit price	1/3 Unit price	1/3 Unit price	1/3 Unit price
Transformer	Unit price	Unit price	Unit price	1/3 Unit price	1/3 Unit price	1/3 Unit price

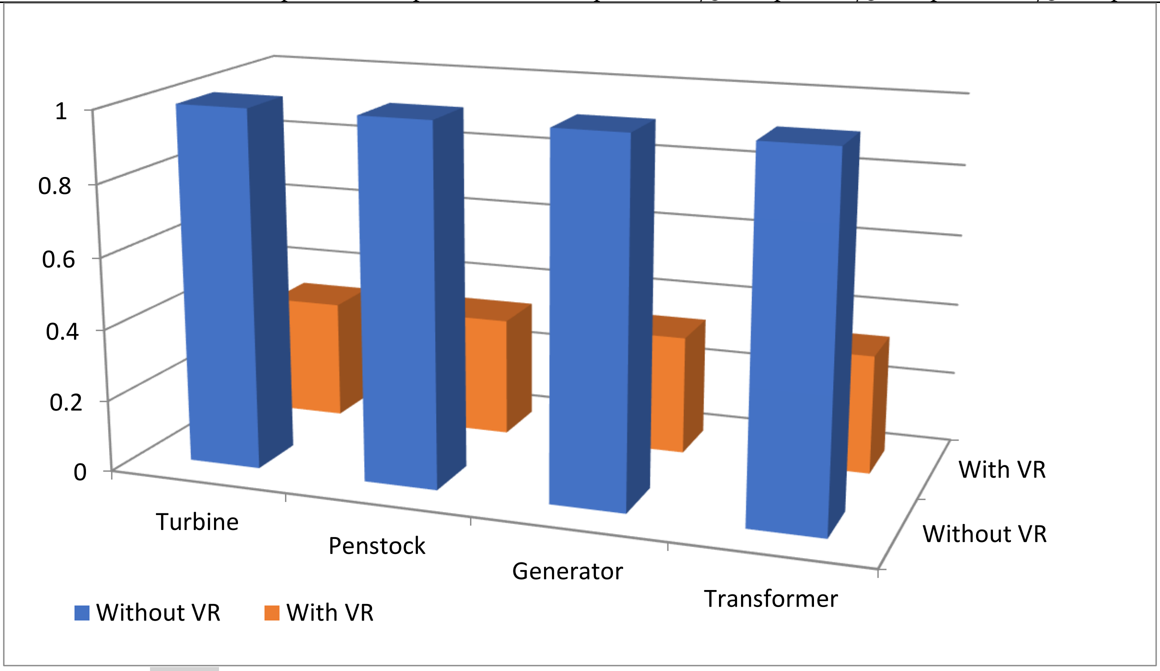

Fig.6 Rates of Reducing the Cost of Establishing a Hydroelectric Station.

5.RESULTS

After we provided an explanation of VR technology, and how to transfer the user to a virtual environment similar to the real environment using specific hardware and software techniques, we linked this technology and tried to benefit from it in the subject of generating electrical power from various sources. The energy sources were divided into two parts. The first is the basic energy sources that generate large amounts of electrical power, such as hydroelectric stations, thermal stations, as well as nuclear plants. A mathematical model was presented as equations for the variables that directly affect the process of generating electrical power for each of these sources. Thus, each of these variables is given a specific symbol in writing a VR program in the event of presenting applied research on this topic, because the current research is only a study and not an application. Returning to energy sources, the second part are secondary or auxiliary energy sources, which cannot be fully relied upon to suffice with generating electrical power at the present time, such as solar energy and wind energy. Therefore, no mathematical model was presented as equations for variables that may affect the process of generating electricity. However, the basic elements that must be available in order to benefit from solar energy have been explained, which are solar panels, inverters, and batteries. For the purpose of clarifying the principle of reducing the cost of large projects when using VR technology, we hypothesized the construction of a hydroelectric power station, which includes some parts whose types are difficult to choose when designing and installing, such as the turbine, the penstock of water, the generator, and the transformer. Since this technology eliminates the need to design the station in a real way and avoids the need to test and install what has actually been designed, which may be repeated two, three or four times, and this means transporting the equipment and returning it two, three or four times as well. In Table 1, we assumed that each process (design, transportation, and installation) would be repeated three times as an average of a power plant construction process. Therefore, the directly appropriate choice for this equipment will reduce the cost to a third, as shown in the diagram of Fig. 6. Of course, repeating the process only twice will reduce the cost by half, and repeating it four times will reduce the cost to a quarter, and so on.

6.CONCLUSIONS

The main conclusions of the present study could be summarized as follows:

- The purpose of this research is to study how to link VR technology to the process of generating electrical power.
- The study aims to identify energy sources, whether major or secondary, then determine the parameters of each source and represent them (parameters) with specific symbols to build the VR program that gives a complete visualization of the process of generating electrical power.
- The research includes requirements for VR technology at the hardware level (glasses, headsets، sensors and cameras) and programming languages (the simplest proposed programs)
- It is worthy to be mentioned that developing this technology leads to reduce the risk and the cost by discover everything concern with the generation issue even before installing and operate the plant.
- VR technology can reduce the cost of constructing a power plant to a third of the expected value after eliminating the design, installation and transportation of equipment, because there is no need to repeat operations more than once.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Aous Naji: Writing - original draft, Idea, Hypothesis, Mathematical models, Conclusion, Data curation. **Ruya Jaafar**: Investigation, Project administration, Writing - review & editing. **Luma A**: Writing - review & editing, Resources.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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NOMENCLATURE

p	Power, W
Q	Discharge water, $\frac{m^3}{sec}$
h	Height, m
η	Efficiency, without unit
O/P	Output Power, kWh
I/P	Input Power, fuel burn

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