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Fuel Cell Evolution

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Abstract

This paper focuses on the progress that has been made in fuel cells through four theories, namely thermodynamics, electrochemistry, electrolyte theories, direct generation physics and finally the application of Ohm's law physics to the fuel cell system. In order to identify the compatibility of the basic theories with these systems. Through this research, we have indicated the need for a unified theory to explain the mechanism of stability and constancy, which leads us to say that they are relatively perfect systems.

Keywords: fuel cell, electrochemical reaction, electrode, electrolyte, power generation, AFC, PAFC, PEFC, MCFC, SOFC, Exchange current density, charge transfer coefficient, ohm losses, resistance.

1. Introduction:

Approximately, 46% of the electricity generated in the world comes from the combustion of fossil fuels that have an impact on emissions Fossil fuel production and combustion.

The possibility of depletion of these resources necessitates obtaining cheap, high-quality energy sources with few harmful emissions to the environment, including renewable energy.

In order to achieve this goal [1]. It is noted that fuel cells provide high efficiency and have harmless emissions [2]. This is what makes us expect that it will be an alternative to internal combustion engines, and provides stationary and portable power through many practical applications for the six main types of fuel cells.

This review includes the major fuel cell types, which are classified according to the electrolyte used, such as AFC alkaline fuel cell, PEFC polymer electrolyte fuel cell, PAFC phosphoric acid fuel cell, MCFC molten carbonate fuel cell, SOFC solid oxide fuel cell. We review the developments and the factors that affected them.

Scientists are interested in studying fuel cells because of the inefficiency of other systems in generating energy.

Recently, concerns about energy resources and environmental pollution have increased, which has led to interest in these systems in power generation with higher efficiency and lower emissions.

In the past, experimental projects for energy applications were limited to public utilities [3], and with scientific progress, researchers became interested in developing types of fuel cells and at the same time planning the infrastructure that will support them.

The following parts of our review deal with the basic theories that explain the mechanisms of fuel cell systems, in order to understand the technical and scientific gradient, and a general review of previous studies, which start from electrochemical and electromagnetic interpretation, then thermodynamic. Finally, the application of physics to fuel cells to identify the compatibility of these systems with previous theories and their relative ideality in terms of efficiency and performance.

2. Electrochemistry of a fuel cell:

In 1800, it was studied by William Nicholson and Anthony Carlyle, the process of electrolysis of water into hydrogen and oxygen [4].

$$2H_2O_{(l)} \rightarrow 2H_{2(g)} + O_{2(g)}$$

Michael Faraday discovered that the amount of elements that are separated by passing an electrode through dissolved salt is proportional to the amount of electric charges that pass through this circuit, and succeeded in deriving two basic laws of electrolysis, the first law states that the mass of the substance produced in an electrode during analysis is proportional with a number Moles of electrons quantity of electricity) transferred at this electrode.

The second law deals with the number of electric charges required to discharge one mole of a substance into an electrode.

The number of "excess" elementary charges on that ion. In 1838, William Robert Grove applied this idea, but in the opposite direction, where he arranged two electrodes of platinum and immersed their ends in sulfuric acid, and the other ends were in two cylinders of oxygen and hydrogen containing a simple level of water, and he found that the direct current had flowed between the electrodes.

Note that the water level rises in both tubes as the current flows. By a group of electrodes in a series circuit, he called it a cell or battery.

Interpretation of Grove results according to Eq

$$2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(l)} + energy$$

Ludwig Mund and Karl Langer conducted several experiments with a gas-fired battery using gaseous coal.

The rising gas was called "almond gas". The current reached 6 amps per square foot (which is equivalent to the surface area of the electrode) with a potential difference of 0.73 volts between the thin perforated platinum electrodes connected to the fuel cell system.

When Friedrich Wilhelm Ostwald founded the field of physical chemistry, he gave an explanation of how fuel cells work [4], [5].

And by identifying the extent of the interdependence between the components of fuel cells and the role of each of them chemically, beginning with the electrodes, the electrolyte, then the oxidation and reduction agents, and finally the anions and cations.

Grove believed that the action in his gas battery occurred at a point of contact between the electrode and the gas, but he could provide no further explanation.

Estwald did pioneering work in linking physical and chemical properties and reactions, and explained the presence of gas in a gas-groove battery, so he is the first to discover the basic chemistry of fuel cells [5].

Francis Bacon developed practical hydrogen and oxygen fuel cells, which convert air and fuel directly into electricity through electrochemical processes. He designed an alkaline fuel cell that used nickel gauze so that the electrodes operated under pressure up to 3,000 psi. use in submarines [7].

And by inventing an alkaline cell in which Bacon used a 10-inch diameter pile as electrodes, it succeeded in being practical and more efficient, and became part of the components of the Apollo spacecraft as a source of energy and water [5].

Meanwhile, Alice Chalmer developed an experimental 20-horsepower electric tractor containing 1,008 individual fuel cells, which, fed with a mixture of gases (mainly propane) could generate an output current of 15 kW and a potential difference of 1 volt of output per cell.

Researchers at the Smithsonian Institution analyzed this experiment and demonstrated that hydrogen is an energy carrier rather than an energy source, which means that it can store and deliver energy in a usable form. Or in other words, hydrogen can be considered as an energy carrier that is produced using various resources, for example fossil fuels, such as natural gas, coal, and other renewable energy resources, such as wind energy, solar energy, biomass, and nuclear energy.

This diversity of energy supplies means not relying on a single external source of energy [6].

Thus, a fuel cell can be defined as a dynamic device that converts the energy of a chemical reaction between hydrogen and a specific oxidizer into electrical energy [7].

The basic principle of the fuel cell mechanism is similar to the battery, but it is designed to replenish the reactants, so it produces electricity from an external source of fuel and oxidizer (oxygen or air), and it consists of an electrolyte layer that separates the electrodes and is under continuous research and updating, taking into account efficiency and performance according to application purposes [7].

2.1 Fuel Cell Mechanism:

In principle, a fuel cell acts like a battery consisting of an electrolyte placed between two electrodes: the anode and the cathode. It does not run out, but it is recharged [7]. It produces energy in the form of electricity and heat when fuel is available. Oxygen passes over one electrode and hydrogen over the other, generating electricity, water, and heat.

This is how hydrogen fuel is fed into the "anode" while oxygen (or air) is introduced into the cell through the cathode. The reaction takes place (see Figure 1) with the help of the catalyst, so the hydrogen atom is divided into a proton and an electron that travel two different paths, so that the proton passes to the negative pole and the electron passes to the positive pole, and thus electricity is generated from the electronic current, and by the meeting of hydrogen and oxygen, a water molecule is formed.

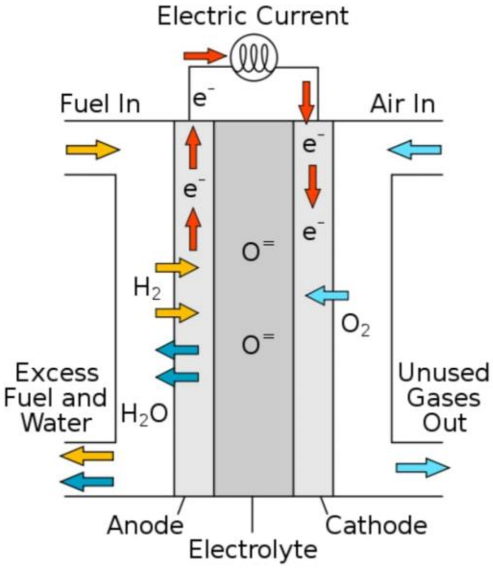

Figure (1)

2.2 Characteristics of fuel cells:

The system consists of individual fuel cells assembled in a sequential arrangement, forming a modular stack, manufactured in sizes ranging from one watt to more than MW [8].

One of the most important components of the system is the fuel handler and stack. Although unaffected by the size factor, we find that fuel cell systems may have sufficient processors to meet a wide variety of applications.

With power needs as small as 10 kW. Across a range of applicable sizes, it delivers acceptable conversion efficiencies.

The fuel cell system remains functional Even in off-design conditions. Cellular system efficiencies often range from 40% to 50% for simple systems over a wide range of sizes. The smallest and most efficient system compared to those offered by fuel cell systems is constructed considering design conditions [8].

Moreover, the conventional system cannot maintain efficiencies comparable to systems for partial load operations. More complex fuels can provide higher efficiencies, for example in a system consisting of a solid oxide fuel pressurized in a cell (SOFC).

With exhaust gas driving a gas turbine, the overall electrical conversion efficiency is up to 60%. In gas turbines, only a conventional combined steam cycle can approach this level of efficiency required at least at design load.

Because fuel cells can operate on lift Efficiency even at relatively small sizes, it fulfills the ambition of cogeneration applications of small size systems [8].

The cogeneration fuel cell efficiency may reach 80% for some energy applications to produce electrical energy or thermal energy to be consumed in water heating and district heating [9].

Hydrogen is produced in the fuel cell stack from the hydrocarbon fuel, and then carbon dioxide is also produced through the fuel oxidation reaction in proportion to the amount of carbon in the primary fuel source.

Thus, the overall system including the fuel processor produces water and carbon dioxide. Fuel cells reduce the emission of hazardous pollutants such as carbon monoxide, nitrous oxides, and sulfur oxides [9].

Carbon dioxide emissions will be lower as a result of higher efficiency and less fuel used, and in some cases these parameters are improved to increase efficiency. power systems [10].

2.3 Electrolytic Classification of Fuel Cells:

Fuel cells were divided according to the type of electrolyte used into six types, as follows:

2.3.1 PEM Proton Exchange Membrane Cells:

PEM was invented by Thomas Grubb and Leonhard Niederach in the 1960s. And when they developed a small fuel cell [4], it was the unit that fueled it Hydrogen is produced by mixing water and lithium hydride, so that the fuel is kept in easily disposable cylinders because they were pressurized and portable, while the platinum catalysts were placed in static with the hull.

These fuel cells operate at a relatively low temperature level (about 175 degrees Fahrenheit), have a high energy density, and have the advantage of being able to quickly change their output to meet required power transitions, and are therefore suitable for many applications such as automobiles, where the fast start-up process is required.

This type of fuel cell is sensitive to impurities, and the cell's output range Generally from 50 watts to 75 kW [11] [12].

2.3.2 Molten Carbonate Cells (MCFC):

Emil Bauer and her co-workers tested high-temperature solid oxide electrolytes, and encountered a problem with electrical conductivity, as well as some conduction-impeding chemical reactions that occurred between the electrolytes and the various gases (including the emission of carbon monoxide). Subsequently, H.G. Brewers and J.J. Ketelar for success in placing restrictions preventing further reactions and, at the same time, focusing on molten carbonate salt electrolytes [5].

The system was soon developed to operate for six months using an electrolyte mixture of lithium, sodium and/or lithium Potassium carbonate, impregnated in a porous sintered tablet of magnesium oxide.

However, they found that there was a slow partial loss of electrolytes in the magma, through interactions with cell support material.

The work of Francis T. Bacon on a molten cell using two-layer electrodes on either side of the 'free molten' electrolyte, while others tested semi-solid or adhesive electrolytes, and 'diffusion' electrodes were placed in place of solid electrolytes.

And in 1965 several molten carbonate cells were tested, with output sizes ranging from 100 watts to 1000 watts, designed to operate on benzene derivatives with the help of an external source of hydrogen.

Molten carbonate fuel cells use an electrolyte consisting of A mixture of molten carbonate suspended in a porous vessel, and a chemically inert matrix, worked at high temperatures, about 1200 degrees Fahrenheit. It takes carbon dioxide and oxygen to deliver it to the cathode.

So far, MCFCs have been proven to be able to operate using hydrogen, carbon monoxide, natural gas, propane, landfill gas, marine diesel and carbon coal and have an output capacity from 10 kW to 2 MW. MCFCs have been tested on different fuels to produce electricity [12].

2.3.3 SOFC:

In 1939 Emil Bauer and colleague H. Brice Pitts Solid Oxide Electrolytes Experiment, Using zirconium, yttrium and cerium, Lanthanum, and tungsten.

The results of the experiments were not satisfactory due to the increased emissions of chemical reactions between the electrolyte and various gases, including carbon monoxide.

He further explored the development of solid oxide technology and reviewed the problems encountered in fuel cells since 1959. These included solid electrolytes, which showed relatively high internal resistance due to their semiconductors.

Many researchers believe Fused carbonate cells are short-lived, hard, non-porous ceramics. It would be the electrolyte that allowed temperatures to be raised - to about 1,800 degrees Fahrenheit.

But one type of SOFC used a set of tubes a meter long. Other variations include:

- A CD-like disc is located above the vessel of the cell structure. a lot of SOFC Designs are Suitable for stationary applications and support Power Units (APUs) used in vehicle options [5], [12].

2.3.4 Alkaline fuel cells (AFC):

Francis Bacon experimented with alkaline electrolytes in 1939, and used potassium hydroxide (KOH) instead of the acidic electrolytes known since Grove's early discoveries. KOH, thus the corrosion of the electrodes was eliminated. Bacon's cell also used "porous diffusion of gases".

as electrodes" rather than solid electrodes in Grove's model. Gas diffusion electrodes have increased surface area. The reaction between the electrode and the fuel, and compressed gases are used to maintain Electrolyte to extend the life of micropores in electrodes.

And by improving the alkaline bacon cell, it was relied upon in many tasks, and it was used in The Apollo spacecraft, as a source of energy, suffices the flight with what it needs of electricity and drinking water and operates at an efficiency of 70% of continuous performance.

Alkaline fuel cells are powered by potassium hydroxide as an electrolyte at 160 degrees Fahrenheit and because it is vulnerable to carbon contamination, it is in constant need of pure hydrogen and oxygen [11].

2.3.5 Phosphoric Acid Cells (PAFC):

Since the discovery of the William Grove gas battery in 1842, acids have been used as electrolytes - sulfuric acid being the base. But phosphoric acid is known to be a poor conductor of electricity, so PAFCs have been slower to develop than other types of fuel cells.

Until G.V. Elmore Phosphoric acid electrolytes and described his experiments with an electrolyte of 35% phosphoric acid and 65% silica powder in a Teflon structure. Unlike sulfur, phosphoric acid is observed. It does not decrease electrolytically during cell operation.

The PAFC cell runs on air rather than pure oxygen. So, it is "an acid cell that has been operated for six months with a density of 90 [milliamperes per square centimeter] and a potential difference of 0.25 volts. "With further testing, I designed a cell that used a reformer or an electric inverter with the development of a plastic-bound electrolyte" [4], [5].

PAFCs:

It generates electricity with an efficiency of more than 40% - and nearly 85% if the steam produced from the cell is used in cogeneration - and is close to about 35% of the electricity grid in the largest countries in the world.

In these cells, liquid phosphoric acid is used and operates at about 450 degrees Fahrenheit. This type of fuel cell has an efficiency of approximately 85% for cogeneration and runs on pure hydrogen as fuel. It can withstand a carbon dioxide concentration of about 1.5%, which expands the selection of different fuels. Noting that in the case of working with benzene derivatives, sulfur must be removed [13] [14].

2.3.6 Direct Methanol Cells (DMFC):

NASA has developed a methanol fuel cell, which has the advantage of providing a longer operating time. On the other hand, lithium batteries, which are considered to have a low ionic current, can be recharged by replacing the fuel cartridge (see Figure 2). Japan developed the cells DMFC Similar to cells PEM; Both use a polymer membrane as the electrolyte. and with DMFC, an n-hydrogen anode catalyst produced from liquid methanol, to overcome the problems of fuel processing. The efficiency of this type of fuel is expected to reach 40%.

It operates at a temperature of between 120-190 degrees Fahrenheit. This is a relatively low range, which makes it an excellent fuel, which may be small or medium sized, to power your appliances.

Mobile phone and laptop. The efficiency of these cells increases with increasing temperature [15].

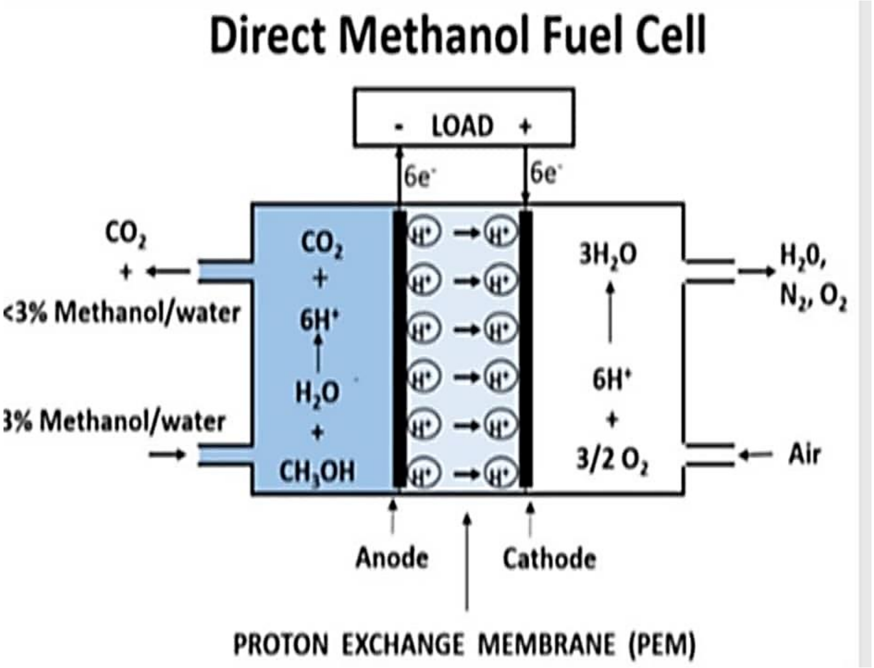

Figure (2)

One of the most important advantages of fuel cell systems compared to conventional energy systems is the high module, efficiency and low emissions harmful to the environment, which made them occupy a wide range of applications. [16].

Hydrogen fuel cell systems are often compact, lightweight, have no moving parts, and do not involve combustion, so they can achieve performance of up to 99.9999%. It is equivalent to less than 1 minute of downtime over 6 years [16], [17].

3. Thermodynamics of a fuel cell:

A fuel cell system allows mass and energy to flow across its boundaries. It is also a finite and controlled volume in which work is obtained by electrons moving through a potential difference, rather than mechanically.

Therefore, they are open thermodynamic systems where the energy transfer equation is:

$$\mathbf{\Delta E = \Delta U + \Delta KE + \Delta PE + \Delta\ (PV)} \qquad \mathbf{(3)}$$

U - internal energy of the system

KE, PE - kinetic and potential energy

PV - volumetric pressure of the workpiece

Internal potential energy:

Enthalpy (H) combines the internal energy.

The equation for the photoelectric work done is:

$$H = U + PV \qquad (4)$$

But enthalpy - is a measure of the total energy of a system Thus, the energy change in the open system is the result of summing Equations 3 and 4:

$$\mathbf{\Delta H = Q - W} \qquad \mathbf{(5)}$$

It is the constant flow equation, where:

ΔKE *and* $\Delta PE = 0$

By studying the reaction in a fuel cell:

$$\mathbf{fuel + oxidizer = products} \qquad \mathbf{(6)}$$

We note that the reaction takes place by the transfer of electrons between the electrodes, according to the equivalent of Faraday's constant in a chemical reaction: 6.023×10^{23} [Avogadro No. (A)] 60

Electrons are transferred According to Faraday's constant:

$$\mathbf{F = A\ e} \qquad \mathbf{(7)}$$

where e is the electronic charge and is equal to (1.6 x 10-19 coulombs) and F is Faraday's constant and is equal to: 3 9 4 6 p coulomb/eq.

These constants are used and represent only one equivalent value Where the chemical change is about the amount of electricity converted.

It is equal to the number of electrons transferred during the reaction fuel + oxidizer = products (6) It depends on the equations of change (n).

- N is obtained from stoichiometry
- Through the application of Eqn. 7 We get the amount of electricity which is what It is transported during interaction by:

Electric quantity = NF (8)

$$w_e = \int_{0,t} Eldt$$

(10)

NF has units of charge (C) (I).

The rate of charge transmission or current flow We also note that E*I in it is characterized by energy units - So is work/time -

The mathematical form of the first law is:

ΔH = Q – W (5)

Since the energy transformation in open systems

We = NFE (9)

It means electrical work, and if there is no other work:

ΔH = Q - NFE (11)

Consider the second law of thermodynamics, we find that the first law does not provide for any Constraints showing the direction of energy transformation Whereas, the energy content depends on the work done equivalent temperature.

This is incorrect because it is impossible to transfer heat efficiently to fill - and vice versa.

In the sense that there is a necessity for the second law because no device can operate in this way or when it is The only effect on the system and the medium around it is The heat absorbed by the system is completely converted into The work done by the system and it is impossible for any periodic process to convert the heat it absorbs the entire system to the work that the system does Secondly, there is no process that consists only of transferring heat from a lower temperature level to a higher one.

This means that the second law does not prevent the Thermal transformation of the workpiece. However, it puts an end to the heat blast So that it can be converted into finite occupation.

And the direction of energy transmission can be determined through the reverse change, so the concept of reflection must be studied - first, and we note that the second law states that the system is reversible.

This concept changes if it remains in equilibrium. It moves from its initial state to its final state depending on the properties of the inverse change - the electrochemical cell - would be ideal.

It is Gibbs definition "If changes occur in the cell while the current is passing through, then all changes that accompany the current can be reversed.

By reversing the current, it would then become the cell, An ideal electrochemical device.

This is how you determine the entropy of a fuel cell. Thus the disorder in the system can be measured.

As a result of irreversible processes, entropy is generated by:

Frictional heat loss

Limited heat transfer

The temperature difference is given as follows:

$$\mathbf{dS = (dQ/T)\ rev.} \qquad \mathbf{(12)}$$

S - entropy

Q - heat

T - temperature

In other words, entropy is a state function (path independent).

$$\mathbf{\Delta S = S2 - S1 =}$$
$$\mathbf{Rev\ 1, 2\ (dQ/T)} \qquad \mathbf{(13)}$$

(integral form of eqn. 12)

Shows that the process is subject to reverse heat Transfer Q rev at a constant temperature to,

$$\mathbf{\Delta S = Q\ rev / To} \qquad \mathbf{(14)}$$

It is an instantaneous mathematical expression where:

$$\mathbf{sum\ \Delta S = system\ \Delta S + surroundings.\ (15)}$$

Equivalence applies to reversible operations as for inequality, it indicates irreversible processes Also, the computed entropy is the result assuming a series of reverse operations At the same initial and final points - This is true because entropy is a function of state.

By applying the second law to fuels, from Equation 11, by applying the first law to fuel cells:

$\Delta H = Q - NFE$ (11)

application of the second law

$Q = T\,\Delta S$ for a reversible system (from eqn.14)

So,

$$\mathbf{\Delta H = T\Delta S - NFE} \qquad \mathbf{(16)}$$

Gibbs free energy (G)

and write it in eqn. 16 is a differential form:

$$\mathbf{dH = TdS - FEdN} \qquad \mathbf{(17)}$$

And since the cell works in the opposite direction:

The energy lost is minimal and the useful work obtained is maximum. It is used to complete the operations that can be performed. It is represented by the Gibbs free energy.

$$\mathbf{dG = -FEdN} \qquad \mathbf{(18)}$$

To calculate the maximum value of useful work

We replace eqn. 18 in Eq. 17 we get:

$$\mathbf{dG = dH - TdS} \qquad \mathbf{(19)}$$

This is the thermodynamic expression for the maximum useful work that can be achieved automatically or out of control.

Thus, we can explain what happened as follows:

$dG = dH - TdS$ (19)

from the scientific side:

H is the total energy of the system

S is an unavailable energy

It represents the amount of loss that cannot be avoided. Thus, G is the available energy with which useful work can be obtained for the system.

G - related to H and S (Eq. 19)

We note that G is not directly related to the interaction in eqn. 6 But the reaction contributes to the resulting energy and the properties of the reactants affect the determination of the reaction products and the free energy of the system.

4. Physics of Direct Generation vs. Electromagnetic Induction and Application of Ohm’s Law:

Fuel cells are devices that use electrochemical reactions to generate electrical energy.

And by generating hydrogen from renewable energy sources, fuel cells have become one of the most demanded technologies. They are completely different from the electrical power generation systems that operate By the mechanical force of heat engines.

Which is not explained by Michael Faraday's principle of electromagnetic induction. Because electricity is generated directly from the oxidation of a fuel and an oxidizing agent and reduction, this is sometimes referred to as direct generation of electricity.

And through an experimental study to analyze the effect of conditions surrounding commercial fuel cells.

And access to the preference in terms of design, production, and system energy density, which has been focused on understanding the various physical phenomena (See Figure 3) within the cell and control mechanisms to improve efficiency and expand field operations and durability, and it was found that there is a significant loss in the potential difference through the surrounding medium, and when the fuel cell is not connected to an external device, the predicted fuel cell potential should converge with the thermodynamic potential of the surrounding medium and the emerging reactants.

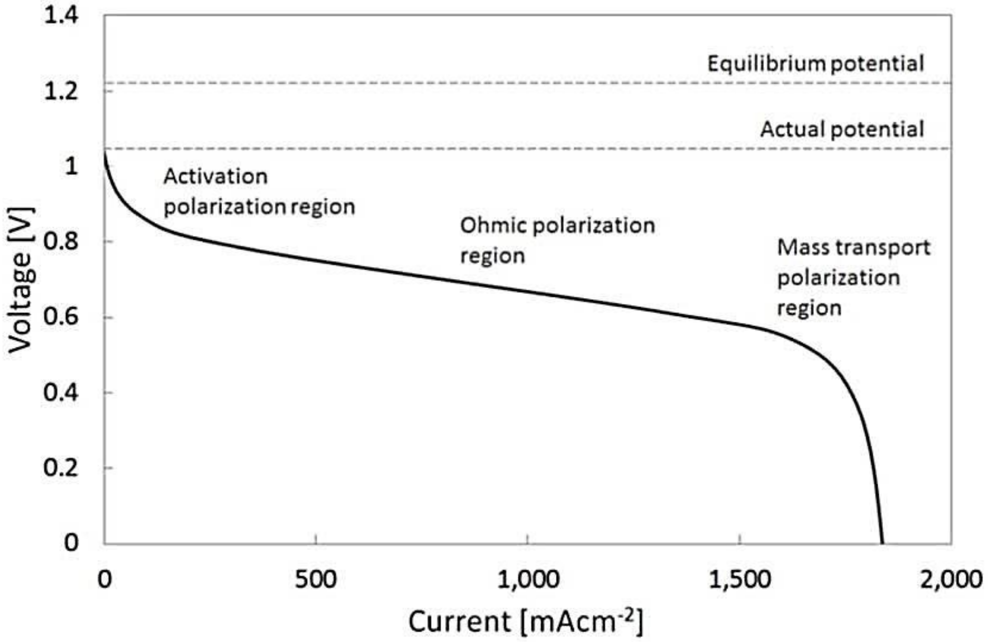

Figure (3): Shows a typical polarization curve of a fuel cell.

However, the fuel cell voltage is much lower [less than 1 volt/cell), it can be attributed to the junction of the inner hydrogen with that in the periphery. When a load is applied to the fuel cells, an additional drop in potential difference occurs, and a consequent drop in resistance, or what is known as ohmic losses, Since there is a necessary need for the energy required to start chemical reactions, this may be an explanation for each linear drop in voltage, which is called a loss of polarization, and occurs on both cathode and anode catalysts.

This phenomenon is often neglected on the anode because its dip process will be less active than on the cathode. Thus, a change in the current density occurs continuously, coinciding with the reaction time, during which the load on the network in the equilibrium state is zero.

Also, the resistance to the flow of electrons and ions through the electrically conductive components of fuel cells are also the cause of the voltage drop, which can be expressed by Ohm's law.

The explanation for this is that the internal resistance of the cell is constant, but it is the ionic resistance that changes. It is the cause of the voltage drop.

5. Conclusions:

The fuel cell structure is made such that the two electrodes (anode and cathode) are aligned with the electrolyte layer; Electrolyte is placed between the two poles. The valve directs the fuel to the positive electrode, to ensure that the fuel oxidation reaction occurs while providing an oxidizing agent to the negative electrode, and adding a certain substance to reduce the reaction of this oxidizing agent.

The load circuit is formed by connecting the connecting wires to the electrodes and the external load, and when the charged particles move inside the electrolyte, current is produced from the cell.

The charge carriers within the electrolyte are composed of positive and negative ions, each with a different direction of motion. In ion-acid fuel cells (phosphoric acid fuel cells, for example), the hydrogen ions (H+) move where the anode is located next to the negative electrode, and reactions occur with oxygen to generate water (Fig. 1). And in carbon fuel cells combined with alkaline electrolytes The carbonate ions (CO32-) in the electrolyte move from the negative electrode to the positive electrode, after it reacts with hydrogen to produce water (see Fig. 2).

The results of the reactions at the electrodes depend on the type of ions, and this is taken into account when designing the structure, the materials used, and a host of additional parameters such as operating temperature, pressure, and effective fuel.

In fact, fuel cells work by supplying the anode with hydrogen and oxygen to the cathode, electricity is generated, and we get water as a result of the reaction.

Hence it can be said that fuel cells are the reverse phenomenon of the electrochemical decomposition of water which produces oxygen and hydrogen in conventional electric power generation, usually using thermal fossil fuels.

In power plants, the chemical energy of the fuel is first converted into heat by combustion to the water boiler. This generated heat is used to produce pressurized steam, which in turn pushes Turbine generator, to convert fluid dynamic energy into mechanical energy, ultimately produce electricity. In contrast to traditional steam turbines or generators, the electrochemical method is indicated for the production of electrical energy Because it is "direct" generation of electricity, it is not subject to Carnot cycle efficiency This limits the maximum efficiency of heat engines for conventional systems.

This means that fuel cells are thermodynamic par excellence and can Extract all of the Gibbs free energy from the conversion fuel into actual work (see Fig. 3).

We note that when hydrocarbons are used as fuel catalysts in the power generation system, the fuel must be converted into Hydrogen-rich gas by chemical reactions to re-form vapor.

We note that fuel cells are relatively ideal systems that operate with higher efficiency and lower emissions, and they also comply with the laws of thermodynamics, and that the chemical processes that convert into electrical energy are only new proof of this ideal thermodynamic system, whose transformations apply the concepts of reverse change.

By reviewing the basic theories and applying the fuel cell to these theories, we find that they represent an ideal system from the ground, and we recommend through this paper the necessity of developing hypotheses for a unified theory that explains the ideal systems, which were presented on the hypotheses of the basic theories.

We expect here that the unified theory will be able to explain and explain the mechanism of stability and constancy, which leads us to say that they are relatively perfect systems.

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18. Figure 1. Courtesy of the US Department of Energy Excellency Energy http://www.eere.energy.gov/ Hydrogen and Fuel Cells /fuelcells/fc_types.html as of March 27, 2007

19. Figure 2. Methanol fuel cell courtesy of NASA "http://www2.jpl.nasa.gov/files//images/hi-res/p48600ac.tif" up to March 27, 2007.