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OPPORTUNITIES AND CHALLENGES FOR FUEL CELLS IN INDIA

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ABSTRACT

India, the country of billion peoples and a developing economy, is one of the countries, which will arrange the energy stream and petition consequence in the 21st century. With high evolution charges of the Indian economy, energy desires are also mounting quickly. An increasing global anxiety over environmental matters and the need for energy safekeeping of the country requires India to follow entirely choices for broadening of fuels and energy springs. In the approaching eras, hydrogen is self-possessed to become a major constituent in India's energy mix for summit the rising energy needs of the budget. India's national energy strategies recognize hydrogen as an auspicious energy storage decision, which will deliver unsoiled and efficient energy to encounter the supplies in power and transportation segments. A National Hydrogen Energy Roadmap, arrangement by National Hydrogen Energy Board, India for the expansion of hydrogen energy related technologies counting fuel cells, has been covered in detail. The most gifted of all fuel cell technologies advanced is proton exchange membrane fuel cell (PEMFC), which works at an inferior temperature. The optional of PEMFC is straight alcohol fuel cell (DAFC), which is straight fed with methanol and ethanol as fuel in its place of hydrogen. The road map is an industry-driven preparation course that suggestions long-term hydrogen energy grounded solutions to India's energy segment. A section of this article offers detailed data about the R&D actions on PEMFC, DAFC and high temperature PEMFC in India. This asylums developmental exertion carried out by the government investigation institutes, universities and private sector administrations. A common of administrations are complicated in essential research, for e.g. polymer sheaths electrolyte, anode and cathode catalysts and membrane electrode meeting and hydrogen storage with actual few tangled in engineering and technology. Approximately institutions are intricate in more application-oriented research such as stack and stability of plant growth and fuel cell bus protest program. The marketplace probable for fuel cell based requests in India is deliberated at the end. India, with a rising economy and an appropriate national energy policy is an enormous potential market for fuel cell founded applications. Motionless markets for fuel cells in India variety from backup power for inhabited applications to incarcerated power cohort for industrial submissions. This item comprises debate on possible of fuel cell founded power generation in extra hotels, procedure industries, color-alkali and dairy business and telecommunication and information technology

business. Fuel cell submissions in the Indian automotive segment are of countless prospects. Early diffusion in this segment will be in buses owing to their central operation, keep and refueling. Light duty vehicle marketplace also demonstrations latent for fuel cell technology execution. India has a large quantity of administrations in the light duty vehicle sort, i.e. passenger car segment.

Key Words: Energy Scenario; Hydrogen Energy; Fuel Cell; Proton Exchange Membrane Electrolyte; Anode; Cathode and Catalyst; Fuel Cell Application.

I INTRODUCTION

Fuel cells are in the premature stages of progress as a competent power generation system. Use of fuel cells in power generation assurances to greatly diminish greenhouse gas emanations through its comparative efficient operation (when compared to conventional technologies). In addition, a fuel cell system with few/no stirring parts bargains a low/ noise-free procedure and can operate on a diversity of fuels, therefore offering numerous aids while used in several of the acknowledged applications today..

In 1970's, fuel cells were used as power generation methods in Apollo space operations. Today, apart from interstellar applications fuel cells are being used in stationary and vehicular power claims. Imminent applications being explored today include laptops, mobile phones and other remote communication applications.

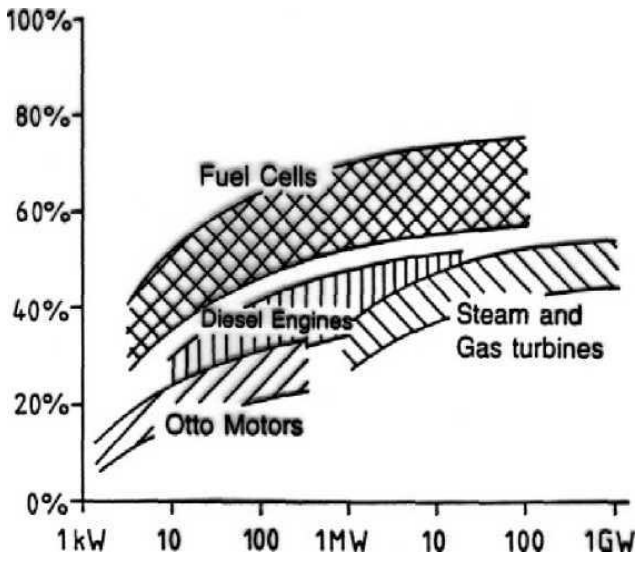

Figure 1*:* Comparison of power overall efficiency vs. plant capacity

A fuel cell comprises of an electrolyte crammed between an anode and cathode. The anode and cathode form the rods of the fuel cell. In a distinctive fuel cell, fuel is nourished constantly to the anode (negative electrode) and an oxidant (often oxygen from air) is fed constantly to the cathode (positive electrode). The electrochemical responses take place at the electrodes to yield an electric current through the electrolyte, while pouring a corresponding electric current that achieves work, on the load. Although a fuel cell is analogous to a typical battery in many means, it diverges in numerous respects. The battery is an energy storage device in which all the

vitality accessible is stored inside the battery itself (at least the reductant). The battery will stop to produce electrical energy when the chemical reactants are spent (i.e., discharged). A fuel cell, on the other hand, is an energy adaptation device to which fuel and oxidant are supplied unremittingly. In principle, the fuel cell harvests power for as long as fuel is provided. The waged of a fuel cell can enlightened with the below governing equations,

At anode,

$$2H_2 \longrightarrow 4H^+ + 4e^-$$

At cathode,

$$O_2 + 4e + 4H^+ \longrightarrow 2H_2O$$

Therefore **overall reaction** is

$$H_2 + 0.5\ O_2 \longrightarrow H_2O$$

At the anode, the fuel (hydrogen) is reacted to yield electron's and H+ ions (or protons) and the oxidant (oxygen) is condensed to form water at the cathode, i.e. the oxygen molecules reply with the electron's from the anode and H+ ions from the electrolysis to produce water. The electrons transportable concluded an exterior circuit, while the protons foldaway concluded the ion-conducting electrolyte. The reactions ensue concurrently and keep uninterruptedly at the electrode shells as long as the gases are provided and the drive or migration of e- and H+ ions is not limited.

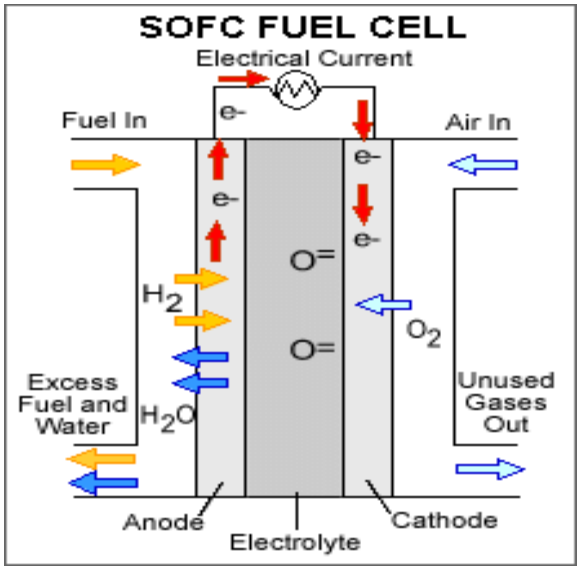

Figure 2*:* Components of a Fuel Cell.

Research and advance accomplishments on fuel cell expertise for the past couple of epochs Following its usage in global applications has primarily focused on development and investigation of a key physical constituent, the catalyst. The catalyst, typically, Platinum (Pt) pays a significant in the electrochemical reactions that revenues place inside a fuel cell. Pt catalyst performances as a sponsor of the ORR which is a lethargic electrochemical reaction in comparison to the HOR happening at the anode. Research with regard to fuel cell catalyst has

focused on two key areas- development of newer catalysts (alloys that are comparatively cheaper) and Pt catalyst size drop. Other areas of present investigation awareness include development of stable electrolyte and carbon upkeep material, effective water and gas conveyance inside the fuel cells.

Below a brief description of the different types of fuel cells is provided.

1.1 Alkaline electrolyte fuel cell (AFC)

The conductor of an alkaline fuel cell can be whichever sodium hydroxide or potassium hydroxide. Potassium hydroxide is used fairly regularly as the electrolyte due its steady physiognomies. The working temperature is about 2500^{o}C with an electrolyte concentration of 85wt% (and < 120^{o}C with a concentration of 35- 50wt %)

An alkaline fuel cell has three main benefits,

1) The initiation over voltage at the cathode is inferior to that of a PEM fuel cell.

2) It uses fairly economy electrolytes and electrodes materials.

3) Demands fewer water managing then a PEM fuel cell.

The electrochemical reactions occurring at the electrodes are,

Anode: $2H_2 + 4OH \longrightarrow 4H2O + 4e^-$

Cathode: $O_2 + 4e^- + 2H_2O \longrightarrow 4OH^-$

Still, the oxidant (typically air) and the fuel have to be free from filths. Even a minor amount of carbon dioxide can abolish the fuel cell.

1.2. Direct Methanol Fuel Cell (DMFC)

Methanol can be used straight as a fuel in a fuel cell with somewhat gentle of electrolyte. Difficulties of storage of hydrogen can be detached with this kind of fuel cell. In addition, the convolution of the system is reduced as direct feeding of the fuel is possible.

Still, numerous other drawbacks challenge the extensive usage of this type of fuel cell. The oxidation of methanol at the anode is an intricate three-step process that diminishes the overall performance of the DMFC fuel cell significantly. In addition to this drawback, fuel limit also poses another chief difficult. The electrochemical reactions going on at the electrodes are,

Anode: $CH_3OH + H_2O \longrightarrow 6H^+ + 6e^- + CO_2$

Cathode: $HO_2 + 6H^+ + 6e^- \longrightarrow 3H_2O$

1.3. Phosphoric Acid Fuel Cell (PAFC)

PAFC is unique of the utmost advanced high temperature fuel cells. The working temperature ranges from 150-220o C. The electrolyte is Phosphoric acid (H_3PO_4), which is an inorganic, extremely constant electrolyte with very squat volatility. The electrolyte solution is confined inside a silicon carbide matrix. The Phosphoric acid fuel cell, smooth though it works a pretty high temperature, wants an extensive amount of noble metal catalysts. The catalyst materials used here have to be sheltered against poisoning similar in any other low-temperature fuel cells.

The electrochemical responses happening at the electrodes of a PAFC, similar **to**PEM fuel cell reactions are,

Anode: $H_2 2H^+ + 2e^- \longrightarrow$

Cathode: $HO_2 + 2H^+ + 2e^- \longrightarrow H_2O$

1.4. Molten Carbonate Fuel Cell (MCFC)

The electrolyte of this kind of fuel cell is a combination of alkali metal and carbonate (usually, a binary mixture of lithium and potassium or lithium and sodium carbonate). At high operational temperatures, the alkali carbonates custom a highly conductive solution with carbonate CO_3^{2-} ions providing the ionic conduction. The electrolyte solution is confined in a matrix of LLAO2.The effective temperature of a liquefied carbonate fuel cell is in the range of 600-700 C. In a melted carbonate fuel cell, CO_2 gas is provided beside with O2 at the cathode side. Significant rewards of this sort of fuel cell are, noble metal catalysts are not vital, and a widespread range of fuels can be applied. For example, hydrocarbons and even carbon monoxide are used, as they can be within rehabilitated to produce H2 or CO gas. The electrochemical reactions happening at the electrode are,

Anode: $2H_2 + 2CO_3 \longrightarrow 2H_2O + 2CO_2 + 4e^-$

Cathode: $O_2 + 2CO_2 + 4e^- \longrightarrow 2CO_3$

1.4. Solid Oxide Fuel Cell (SOFC)

Now the electrolyte comprises of an ion-conducting ceramic material, Zirconia drugged with 8-10 mole% of yttria (yttria- stabilized zirconia). The cell works at a temperature of approximately 1000o C and the ionic transmission takes pace with the assistance of oxygen ions. Solid oxide fuel cell is humbler in perception and strategy, even when linked to MCFC. Reutilizing of C02 is not obligatory. Numerous hydrocarbons and carbon monoxide can be castoff as a fuel. The electrochemical responses happening at the conductors are,

Anode: $2H_2 + 2O^- \longrightarrow 2H_2O + 4e^-$

Cathode: $O_2 + 4e^- 2O^- \longrightarrow$

II HYDROGEN ENERGY AND FUEL CELL TECHNOLOGY IN INDIA

For over an era, the Ministry of New and Renewable Energy (MNRE) has sustained research and demonstration deeds to develop hydrogen and Fuel Cell technologies and their solicitations in the nation. The Ministry newly operation the National hydrogen Board to draft the National Hydrogen Energy Road Plan and obtainable the similar to key investors during a National Meeting on 4th June 2007 in New Delhi. The main unbiased of the National Hydrogen Energy Road Map is to identify the path that would lead to a steady outline of Hydrogen Energy in the country. The Road Map similarly purposes to fast-track commercialization efforts and simplify formation of Hydrogen Energy Set-up in the country.

The National Hydrogen Energy Road Map will bring a complete approach to the expansion of the machineries of the hydrogen energy system, extending from manufacture, storage, conveyance, distribution, applications, security and standards, learning and consciousness among others. The Road Map acclaims that a strong public-private enterprise assigning the total hydrogen energy system for the execution of its proposal be developed.

III APPLICATIONS IN IC ENGINES AND FUEL CELLS

Across the world, fuel cell technologies are quiet in the initial stages of growth. Numerous technological problems regarding choice of materials, developments in strategy and performance of fuel cell satchels and systems are yet to be completely set. Progressive research technology growth and rally of fuel cell technology is obligatory in India.

The Road Map acclaims that public-private enterprises be customary to move from the research laboratories to industries for ultimate commercialization of altered technologies in India. In accumulation, it also endorses that demonstration projects are rapidly taken up which would not only deliver functioning experience in key hydrogen submissions such as dispersed power generation and custom in automobiles, but also simplify creation of provision infrastructure over public-private partnership. Such demo missions would also aid development of low rate, safe and consistent technologies for production of hydrogen, its storage and safe conveyance and distribution.

IV OVERVIEW OF HYDROGEN AND FUEL CELL INDUSTRY IN INDIA

A majority of R&D deeds on Hydrogen and Fuel Cell technologies is presence undertaken by public research institutions like CSIR, BHEL Ltd and roughly fairly few private industrial houses such as SPIC (Southern P petrochemical Industrial Corporation).

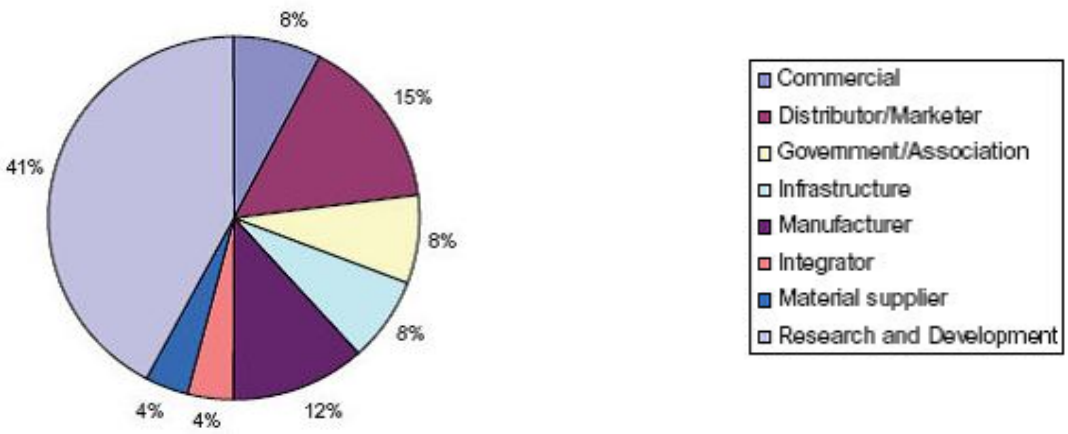

Figure 3: Organization those involved in Hydrogen and Fuel Cell technologies (by type)

In the India context, a huge amount of research is intensive on developing minor immobile applications using fuel cells, which suggestions the greatest budding at contemporary. Industrial operators have long used orthodox

sources to supply their own dispersed power and are now considering towards fuel cells to offer also stationary snarl power or the foremost source of power in imminent. With the predominant condition of irregular stock of power, power outages even in major cities, inactive fuel cell systems could benefit meet the essential demand efficiently. The automotive segment is the following utmost common application emphasis of fuel cell producers in India.

V CRUCIAL COMPANIES WAGED ON HYDROGEN AND FUEL CELL TECHNOLOGY IN INDIA

A transitory portrayal of the efforts undertaken by mutually public and private sector establishments in the development of fuel cell and hydrogen technologies is provided beneath.

Banaras Hindu University (BHU)

BHU is resonant out R&D activities on metal hydride storage schemes for hydrogen and also the usage of hydrogen in internal combustion engines. In 2001, BHU has led field trial and testing of 10 motorcycles. Newly in 2004, field trials on a three-wheeler successively on hydrogen were accompanied.

Bharat Heavy Electricals Limited (BHEL)

BHEL has been occupied on the advance of PAFC and MCFC technologies for dispersed power generation. The company also emphases on developing reagents and fuel improvers for procedure in fuel cell power pants. A fresh advance affects to the work, being done on the development of 50 kW sack PAFC knowledge.

Indian Institute of Technology (IIT)

Indian Institute of Technology (IIT), Madras is intricate in the growth of a 250 watt DMFC sack. IIT Madras has led innovative studies on hydrogen storage in carbon nanotubes.

All-embracing work, is being undertaken at IIT Madras on the growth of new catalysts, catalysts metal-alloys and membranes for custom in PEM fuel cells.

Indian Institute of Technology IT), Bombay

Is intricate in the progress of CFD models of fuel cell systems.

Southern Petrochemical Industries Corporation Science Foundation (SPIC- SF)

Southern Petrochemical Industries Corporation Science Foundation (SPIC-SF) is affianced progress of PEMFC technology for claims that range from stationary (UPS systems, etc.), portable and transportation. The centre is also tangled in designing PEM electrolyze and hydrogen sensors. They have likewise verified a fuel cell battery hybrid vehicle by means of a 10 kW PEM power plant.

National Chemical Laboratory (NCL), Pune:

NCL takes synthesized proton-conducting membranes by means of surface fictionalization. Membranes having

decent proton transport behaviour have been identified for custom as electrolytes in batteries and fuel cells.

Indian Oil Corporation Limited

Indian =1 Corporation is contributing in a project to familiarize hydrogen-CNG bends on a trial basis in existing CNG vehicles in the capital city. The company functions a hydrogen administration facility at its R&D centre in Faridabad. The planned project aims to enhance the hydrogen-CNG bend for maximum recital and minimum discharges in major Indian cities.

Indian Institute of Science (IISc), Bangalore and Central Glass & Ceramic Research Institute (CGCRI), Kolkata

IISc and CGCRI are elaborate in emerging SOFC technology for immobile applications. A methanol reformer was established and integrated through a fuel cell system by IISc, Bangalore. Work, on developing a DMFC is underway at IISc.

Mahindra & Mahindra Ltd

Mahindra & Mahindra Ltd is the second major automotive producer in India. The company is presently occupied on alternative fuel technologies for automotive submissions. It is whispered that they are a so employed on fuel cell and hybrid vehicles.

Tata Motors

Tata Motors, India's third largest maker of inside cars, is presently in talks with builders of hybrid engines and fuel cells, such as Ballard Power Systems for familiarizing fuel cell technologies in their passenger car models.

Telecommunications Consultants India Ltd (TCIL)

Telecommunications Consultants India Ltd (TCIL) has arrived into a non-exclusive contract with US fuel cell manufacturer.

VI CONCLUSIONS

Numerous financial and environmental drivers are encouraging emerging countries like India to appraise fuel cells. The growth of novel fuel cell technology that is profitable, suited to native needs, and employs region-specific and opportunity fuels must be commercially effective. This paper has emphasized the Indian condition with respect to the necessity for fuel cells, the power generation requirements, and identified precise fuel supply strategies to meet any growing in fuel cells.

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