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RENEWABLE HYDROGEN BASED DISTRIBUTED POWER GENERATION SYSTEMS

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ABSTRACT

The centralized power grid failure that occurred in the North American continent on August 2003 highlighted the new set of challenges encountered by the conventional power generation and distribution systems. The profound dependence of such systems on fossil fuel producing economies and the resulting environmental concerns have been the issues of current debate. This paper elaborates on the present day energy crises and the non reliability of the traditional generation systems. It proposes a steadfast and a full proof solution in form of the distributed generation systems pooled to renewable energy sources and subsequently highlights the need to evolve a distributed Hydrogen infrastructure.

1. INTRODUCTION

The recent blackout in the Northeast yet again demonstrated the extent to which the world relies on the elusive kilowatt-hour and how susceptible the socio-economic and commercial sector is to its fluctuating supply leading to an array of resulting crises. However all the crisis related discussions have identified certain common themes, such as a need to improve reliability of the system through better design; a need to diversify supply; increase the use of renewable energy and not to rely primarily on one type of fossil fuel or another be that gas, coal or nuclear. Energy efficiency and clean distributed generation technologies are important elements in the context of a comprehensive energy policy debate. Evolution of the decentralized Hydrogen infrastructure based on renewable energy resources has the potential to eliminate the energy related crises and the associated issues regarding inherent drawbacks of the conventional centralized grid supply system.

2. CURRENT ENERGY CRISIS - EFFECTS AND AN APPROACH

On a global scale, power supply is the most capital-incentive sector of all. Every industry and every aspect of social progress is heavily dependent on energy. The entire economic and commercial sector stretching over the vast continents could be adversely affected if the conventional methods of centralized generation, transmission and distribution depending on the fossil fuel economy persist. Fossil fuels reserves are limited, in particular, those of cheap oil. In the coming decades, global energy shortages, rising prices and risks of conflicts for resources undermining international security are imminent. The environmental degradation and inflating fuel prices have also heaped on the problems. The main burden for these reductions in emissions inevitably falls on the developing world since they have yet to build the electricity infrastructure and supply. The problems will only multiply if power system authorities collectively continue to follow the current model of conventional large-scale central power stations with elaborate and complex distribution and transmission systems.

In the escalating energy and related environmental degradation crisis proceedings on a multinational scale, it is important not to lose sight of several universal trends that could be just as easily implemented by Western nations, developing countries and nations in transition. A stronger emphasis on energy efficiency can certainly form the foundation of a new global energy policy that will not only improve overall system reliability and environmental quality all around but also allow for growth on a larger scale without escalating related air quality and resource depletion concerns. It is time to step back and take a comprehensive approach to solve the energy reliability and supply issues widely.

3. SOLUTION - DISTRIBUTED AND RENEWABLE POWER GENERATION

3.1 Significance of decentralized power generation systems:

The generation of electricity close to loads has advantages that need to be incorporated into the transmission pricing structures and the benefits delivered to the embedded generators and their customers. Evolving distributed generation technologies such as fuel cells, gas turbines and solar can prove to be an asset in this direction.

Briefly, the merits of deregulated power generation can be outlined as:

- Greater system efficiency due to elimination of transmission and distribution losses.
- Independence from the fluctuating and non-reliable centralized grid supply.
- Provision for on-site co-generation facilities thereby providing a supplemental utility.
- Generating the otherwise economically non-viable infrastructure for the implementation of renewable energy sources.
- Reduction of dependence on fossil fuel producing economies and thereby rendering isolation from inflation of fuel prices.
- Smooth incremental curve of the generating capacity within a developing network. This is in contrast to the centralized generation where lump-sum capital investment and setup is desired.
- Facilitation of reserve generation capacity thereby improving the load curve.
- Appropriately designed distributed inverters can actively cancel or mitigate transients in real time at or near the customer level, improving grid stability.
- Decentralization in turn boosts the Hydrogen economy where cost of piping the energy in the form of Hydrogen is reduced to 25% as against the transmission of Electric power.

There is currently an array of deregulated power supply sources varying in the generating capacity, cycle efficiency, capital investment costs and commercial availability status as can be illustrated in Table 1. The transformation of modern distributed generation system from traditional systems has been in the location and size (1 to 10 MW) of the plant layout and the technology implemented within.

3.2 Renewables: a Potential asset

Analysis of existing scenarios that includes consistent descriptions of possible futures of energy systems show that only a combination of efficiency and fuel switch strategies and consequently the expansion of renewable energies, allows all sustainability deficits of today's energy supply systems to be overcome.

Table 1: Statistical comparison of deregulated power generation systems [4]

	Status	**Size**	**CYCLE Eff. (%)**	**Installed Costs $/kw**	**Total Cost $/kwh**
Steam Turbines	Commercial Avail.	50 kw – 200 mw	12 – 38	400 – 1000	0.03 – 0.06
Reciprocating Engine	Commercial Avail.	20 kw – 20 mw	28 – 38	500 – 1400	0.06 – 0.09
Combustion Turbines / CC	Commercial Avail.	500 kw – 500 mw	21 – 65	600 – 900	0.04 – 0.08
Micro turbines	Commercial Avail.	30 kw – 300 kw	20 – 28	600 – 1000	0.06 – 0.10
Fuel Cells	Commercial Avail.	5 kw – 3 mw	36 - 60	1900 – 3500	0.06 – 0.10
Photovoltaics	Commercial Avail.	1 kw +	10 - 20	5000 – 10000	0.10 - 0.20
Wind Turbines	Commercial Avail.	750 kw +	13 MPH plus	1000 – 1500	0.10 - 0.20

There have been several crucial global benefits from a rapid and progressive transition to renewable energies:

- The renewable systems render near zero environmental degradation.
- The primary source of power in this form of generation is virtually free of cost.
- The ability to customize an energy system to the needs of the individual consumer is one of its unique features.
- The renewable source in return acts as a strong driving factor in the decentralization of power generating systems.
- Reduced costs of energy units consumed can help in reduction in the payback periods of the capital investment of the utility.
- Renewable energies require the use of variety of resources and many technologies: increased diversity for greater supply security.

- Renewable energies offer countries in transition the chance of leapfrogging in development: straight into renewable technologies instead of detouring through intermediate fossil fuel capacities.

3.2.1 Current scenario and scope for wide scale evolution

Along the path to full completion, renewable energy has encountered numerous barriers including legislative inadequacies, high production costs and powerful fossil fuel lobbies. The share of world energy use indicated in Figure 2 suggests that currently the majority of the energy demands are fulfilled through fossil fuels.

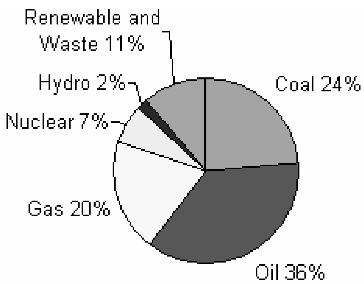

Figure 1: Share of world energy use [5]

The cause of hindrances to the evolution of a green energy system and the steps to resolve them can be enlisted as under:

- Studies have established that the state tax and spending policies tend to favour fossil-fuel technologies over renewables.
- Many of the benefits of renewables, such as reduced pollution and greater energy diversity, are not reflected in market prices.
- The inherent characteristics of renewable sources like wind and solar generated electricity are challenging power quality management due to intermittence. Such plants connected to weak, isolated grids may not provide a reliable power supply.

To bring about a wide scale transition to renewable distributed energy systems, efficient modifications of the socio-economic structure and governing polices have to be enacted wherein a transition to a Hydrogen economy can be evolved.

4. HYDROGEN ECONOMY: A WAY OUT

The Hydrogen fuel cell system not only facilitates deregulated renewable power generation but is also the most energy efficient and concentrated source of power having high energy density. Such a system is not only emission free but also eliminates the complexities of power generation. It provides a flexible solution for standalone grids where it invests in energy storage systems using hydrogen as the universal energy vector.

A fuel cell is an electrochemical device that converts the chemical energy of a fuel directly into electrical energy. Intermediate conversions of the fuel to thermal and mechanical energy are not required. Figure 2 indicates the flows and reactions in a simple fuel cell. Unlike ordinary combustion, fuel (hydrogen-rich) and oxidant (typically air) are delivered to the fuel cell separately. Electrochemical oxidation and reduction reactions take place at the electrodes to produce electric current. The primary product of fuel cell reactions is water.

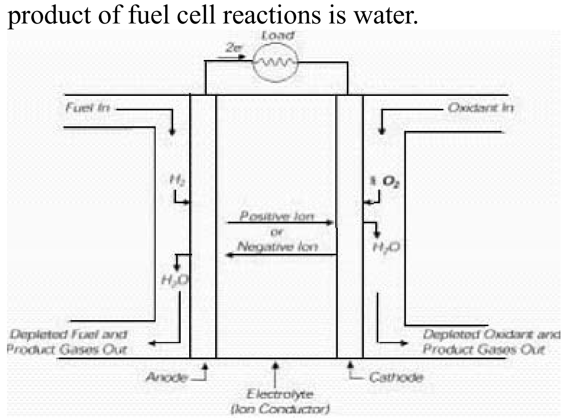

Figure 2: Schematic view of a Hydrogen fuel cell [3]

The key features of the hydrogen fuel cells that make them such a viable tool for the integration of renewable energy to decentralized market are:

- High efficiency (refer Figure 3),
- Low chemical, acoustic, and thermal emissions,
- Siting flexibility,
- Reliability,
- Low maintenance,
- Excellent part-load performance,
- Modularity,
- Fuel flexibility enabling hydrogen production from solar and/or wind hybrids and even from biomass gasification.

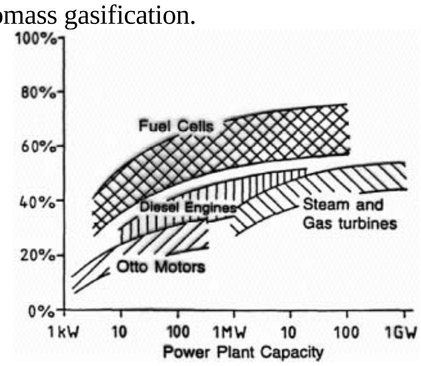

Figure 3: Comparison of power plant efficiencies [2]

The Hydrogen fuel cell would be of most use in one of two ways:

- For a utility with an existing solar, wind or hydro power system, the fuel cell could be used for backup power in place of an engine generator. Given that an engine generator operates at approximately 30% efficiency and the least efficient fuel cell currently offers 40% efficiency (up to 80-90% if by-product heat and/or steam are used for other heating needs), the advantage is clear.[2]
- For a utility without an existing alternative energy system, a larger capacity fuel cell could comprise their primary power system. A wind turbine and/or solar panels could be added to power the water electrolyser or fuel reformer, and the entire power system would be virtually self-contained.

The market segmentation: The most significant competition, both among fuel cell types and with other technologies, occurs in the light commercial sector (refer Table 2). Fuel cells, Photovoltaic arrays, engines, and micro turbines are all expected to be viable options. Light commercial markets are likely to have some cogeneration needs as well. The remote area power installations in the residential sector seem likely to be dominated by fuel cell and solar technology since the overheads of Hydrogen production through solar electrolysis, wind turbines and biomass gasification are projected to drastically reduce in upcoming decades.

Table 2: Markets for fuel cells and competing technologies [1]

Residential (1-15 kW)	**Light commercial (25-250 kW)**	**Commercial with Cogeneration (50kW-3MW)**	**Industrial & Distributed (3-50 MW)**
PEM	PEM	PAFC	MCFC
SOFC	PAFC	MCFC	SOFC
Solar Arrays	SOFC	SOFC	Gas turbines
Stirling engines	Solar Arrays	Micro-turbines	
	IC Engines		
	Micro-turbines		
	Stirling Engines		

PEM: Proton Exchange membrane, SOFC: Solid Oxide Fuel Cells, PAFC: Phosphoric Acid Fuel Cells, MCFC: Molten Carbonate Fuel Cells.

5. THE SOUGHT AFTER ACTION PLAN

For a wide scale evolution of distributed generation technologies based on renewable hydrogen economy, each sector of the socio economic structure including the governing authority, Educational, Industrial and commercial sector have a key task to execute:

- The federal government's role would be to remove financial and non financial barriers to the implementation of commercial technologies. It also plays a critical role in addressing the code, siting and other zoning issues.
- The role of academia which includes academic institutions and outreach organizations; would be to increase public awareness about hydrogen through education on hydrogen energy systems and the true cost of fossil fuels.
- The role of industry can include definition of the energy needs of the marketplace and creation of combinations that tailor hydrogen products and systems which meet those needs in a sustainable and economic manner.

6. CONCLUSION

Current worldwide electric power production is based on a centralized, grid-dependent network structure. This system has several disadvantages such as high emissions, transmission losses, long lead times for plant construction, and large and long term financing requirements. Distributed renewable power generation is an alternative that is gathering momentum, and modern technologies, such as fuel cells, are likely to play an increasing role in meeting ever-increasing power demands.

Some experts may argue that renewable Hydrogen energy and distributed generation is not a cost effective solution; however it is to be remembered that fossil fuel power plants rely on finite resources and have inherent human health and environmental costs which do not appear on the balance sheet of any power plant.

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