A New Generation Hybrid Hydrogen Power Plant

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Abstract— This paper describes about the Hydrogen power plant and its potential that can be harnessed in the future to meet the current energy demand. With detailed description of the Gas turbine and the AC/DC generator, focus has been given on the interconnection of the generators with the grid along with the problems associated. The use of power electronics in the circuitry and their applications has also been emphasized. In the end a voltage stability analysis has been done with respect to various models of the Gas turbines to find the best way to clear faults and have optimum output. In electricity generation, a generator is a device that converts mechanical energy to electrical energy for use in an external circuit. The source of mechanical energy may vary widely from a hand crank to an internal combustion engine. Generators provide nearly all of the power for electric power grids. A phase angle regulating transformer, phase angle regulator (PAR, American usage), phase-shifting transformer, phase shifter (West coast American usage), or quadrature booster (quad booster, British usage), is a specialized form of transformer used to control the flow of real power on three-phase electricity transmission networks. Output efficiency of power plant is approximately 48% and this plant is pollution control of carbon dioxide 40% with compare to thermal power plant.

Key words: Power Scenario in India, Renewable Energy, Hydrogen Power Plant, Hybrid Power Plant

I. INTRODUCTION

A. Power Scenario in India

The proposed power plant used hydrogen energy that can convert hydrogen gas energy into electrical energy for various uses. This plant is pollution control of carbon dioxide 40% with compare to the existing Thermal power plant. The electricity sector in India supplies the world's 6th largest energy consumer, accounting for 3.4% of global energy consumption by more than 17% of global population. The Energy policy of India is predominantly controlled by the Government of India's, Ministry of Power, Ministry of Coal and Ministry of New Renewable Energy and administered locally by Public Sector Undertakings (PSUs). About 70% of the electricity consumed in India is generated by thermal power plants, 21% by hydroelectric power plants and 4% by nuclear power plants. More than 50% of India's commercial energy demand is met through the country's vast coal reserves. The country has also invested heavily in recent years in renewable energy utilization, especially wind energy. In 2010, India's installed wind generated electric capacity was 13,064 MW. Additionally, India has committed massive amount of funds for the construction of various nuclear reactors which would generate at least 30,000 MW. In July 2009, India unveiled a $19 billion plan to produce 20,000 MW of solar power by 2020. Due to the fast-paced growth of India's economy, the country's energy demand has grown an average of 3.6% per annum over the past 30 years. In December 2010, the installed power generation capacity of India stood at 165,000 MW and per capita energy consumption stood at 612 kWh. The country's annual energy production increased from about 190 billion kWh in 1986 to more than 680 billion kWh in 2006 and increased in the upcoming year. The total demand for electricity in India is expected to cross 950,000 MW by 2030. According to a research report published by Citigroup Global Markets, India is expected to add up to 113 GW of installed capacity by 2017. Further, renewable capacity might increase from 15.5 GW to 36.0 GW.

1) Technical Information/ Data

Major PSUs involved in the generation of electricity include National Thermal Power Corporation (NTPC), Damodar Valley Corporation (DVC), National Hydroelectric Power Corporation (NHPC) and Nuclear Power Corporation of India (NPCI). Besides PSUs, several state level corporations, such as Tamil Nadu Electricity Board(TNEB) in Tamil Nadu, Maharashtra State Electricity Board(MSEB)in Maharashtra, Kerala State Electricity Board(KSEB) in Kerala, in Gujarat (MGVCL, PGVCL, DGVCL, UGVCL four distribution Companies and one controlling body GUVNL, and one generation company GSEC), are also involved in the generation and intrastate distribution of electricity. The Power Grid Corporation of India is responsible for the inter-state transmission of electricity and the development of national grid.

2) Demand

Electricity losses in India during transmission and distribution are extremely high and vary between 30 to 45%. In 2004-05, electricity demand outstripped supply by 7-11%. Due to shortage of electricity, power cuts are common throughout India and this has adversely effected the country's economic growth. Theft of electricity, common in most parts of urban India, amounts to 1.5% of India's GDP. Despite an ambitious rural electrification program, some 400 million Indians lose electricity access during blackouts. While 80 percent of Indian villages have at least an electricity line, just 52.5% of rural households have access to electricity. In urban areas, the access to electricity is 93.1% in 2008. The overall electrification rate in India is 64.5% while 35.5% of the population still lives without access to electricity. According to a sample of 97,882 households in 2002, electricity was the main source of lighting for 53% of rural households compared to 36% in 1993. Multi Commodity Exchange has sought permission to offer electricity future markets.

B. Generation

The various generation data for the information prospective included in the section. The Grand Total Installed Capacity (as on 30-09-2010) was 164,835.80 MW. The major contribution for the energy generation in-context of country is contributed by Thermal Power Plant having the installed capacity as of 30-11-2010 is 108362.98MW which is 64.6% of total installed capacity. At the same time the installed base of Coal Based Thermal Power is 89,778.38 MW which comes to 53.3% of total installed capacity, moreover the installed capacity of Gas Based Thermal Power is 17,374.85 MW which is 10.5% of total installed capacity and installed capacity of Oil Based Thermal Power is 1,199.75 MW which is 0.9% of total installed capacity. There is as well minor contribution from twenty nuclear power reactors, produce 4,780 MW of the energy.

C. Renewable Energy

India is facing an acute energy scarcity which is hampering its industrial growth and economic progress. Setting up of new power plants is inevitably dependent on import of highly volatile fossil fuels. Thus, it is essential to tackle the energy crisis through judicious utilization of abundant the renewable energy resources, such as Solar Energy, Biomass Energy, Wind Energy and Geothermal Energy. Apart from augmenting the energy supply, renewable resources will help India (country) in mitigating climate change also. Till time India is heavily dependent on fossil fuels for its energy needs and it's very known that the same is going to exhaust one day in nearby future. Most of the power generation is carried out by coal and mineral oil-based power plants which contribute heavily to greenhouse gases emission. The average per capita consumption of energy in India is around 500 W, which is much lower than that of developed countries like USA, Europe, Australia, Japan etc. However, this figure is expected to rise sharply due to high economic growth and rapid industrialization. The consumption of electricity is growing on the worldwide basis. Energy is a necessity and sustainable renewable energy is a vital link in industrialization and development of India. A transition from conventional energy systems to those based on renewable resources is necessary to meet the ever-increasing demand for energy and to address environmental concerns. India has a large potential for Renewable Energy (RE), an estimated aggregate of over 100,000MW. In addition, the scope for generating power and thermal applications using solar energy is huge. However, only a fraction of the aggregate potential in renewable, and particularly solar energy, has been utilized so far. India is planning to add about 19,500 MW power generating capacity from renewable by the end of 11th plan (2011-2012). As per CEA's fourth National Power Plan, anticipated capacity additions from Renewable Energy sources in presented in the following table: The following table gives the estimated potential & cumulative achievement in Renewable Energy as of 30th September 2013. Hydrogen can be produced from fossil fuels or from water splitting and when hydrogen is derived from hydrocarbons (fossil fuels), the chemical energy to be stored in the hydrogen is already present in the primary fuel. The key challenges to this form of production lie in controlling the chemical reactions and the extraction of hydrogen. Production from fossil fuels are require CO_2 capture and sequestration. Conversely, extraction of hydrogen from water requires that energy be supplied from an external resource, but does not present the challenge of unwanted emissions at the point of conversion. Hydrogen's appeal as an energy carrier is limited by its ability to be efficiently stored. Many energy conversion systems that would use hydrogen must operate intermittently and thereby require a reservoir of hydrogen. This reservoir must be of reasonable size and weight, and cannot waste a significant fraction of stored energy in the filling and venting processes. The only by products of the hydrogen fuel burning process are hot air and water vapor. These two are used to produce steam and further steam can be utilized by a coal-fired plant to produce another potential four megawatts of energy. Invensys Process Systems (IPS) will look after the safety of the plant. It will also be providing the distributed control system for the hydrogen plant. The Trico emergency shutdown system will look after the protection for heat recovery steam generator and electrical systems and shutdown command to the gas turbine system. The various processing section of the Hydrogen Power Plant includes: Steam methane reforming, in which, High-temperature steam is combined with methane in the presence of a catalyst to produce hydrogen. This is the most common and least-expensive method of production in use now a days. Electrolysis the process having electric current is used to "split" water into hydrogen and oxygen. Gasification, in which, Heat is applied to coal or biomass in a controlled oxygen environment to produce a gas that is further separated using steam to produce hydrogen. Nuclear high-temperature electrolysis that uses heat from a nuclear reactor is used to improve the efficiency of electrolysis, again splitting water to make hydrogen. Photo biological microbes, having certain microbes produce hydrogen as part of their metabolic processes. Artificial systems can encourage these organisms to produce hydrogen through the use of semiconductors and sunlight, improving their natural metabolic processes. Photo electrochemical system uses semiconductors and sunlight directly to make hydrogen from water [2] [3] [4] [6] [9] [12] [13] [14[16].

II. WORKING OF PROPOSED POWER PLANT

Hydrogen is efficient fuel to use to generate electricity. It is available in great amount and does not put negative effects like emission of harmful gases or greenhouse effect. This non-toxic gas is easy to produce from many renewable energy sources. Many studies have proved that hydrogen energy is the only alternative fuel that can reduce this world's dependence on oil with reduced greenhouse effect. In this way use of this renewable energy is playing an important role in reducing future climate impacts and energy supply concerns. Today many buildings are powered by hydrogen energy systems, and these buildings use this energy directly when available in surplus. A building that works with power generated by hydrogen energy combines a 750 kW wind turbine, 30 kW electro lyre, 10 kW hydrogen fuel fell and a geothermal source heat pump. New addition to this infrastructure is charging point that carries generated current from one point. There are many organic compounds that are rich in hydrogen, prominently hydrocarbons that is major source for many other flues like gasoline, natural gas, methanol, and propane. Under process of reforming hydrogen can be separated from hydrocarbons that are used to generate electric current.

Electricity generated from solar power is used to split water into hydrogen and oxygen. Oxygen is released into the atmosphere, while hydrogen is liquefied and stored at a very low temperature (-253 °C). By cooling hydrogen to -253 °C, hydrogen is shrunk to a thousandth of its original volume. During internal combustion, the hydrogen combines with oxygen. The resulting energy powers the vehicle, while the hydrogen is returned to the environment as water. The various steps of the energy generation in the proposed power plant involves: Fuel-where some of power plants run on hydrogen, while others use oil, natural gas, or methane gas from decomposing rubbish. Furnace-the fuel is burned in a giant furnace to release heat energy. Turbine-the steam flows at high-pressure around a wheel that's a bit like a windmill made of tightly packed metal blades. The blades start turning as the steam flows past. Known as a gas turbine, this device is designed to convert the steam's energy into kinetic energy. For the turbine to work efficiently, heat must enter it at a really high temperature and pressure and leave at as low a temperature and pressure as possible. Cooling tower-the giant, jug-shaped cooling towers you see at old power plants make the turbine more efficient. Boiling hot water from the steam turbine is cooled in a heat exchanger called a condenser. Then it's sprayed into the giant cooling towers and pumped back for reuse. Most of the water condenses on the walls of the towers and drips back down again. Only a small amount of the water used escapes as steam from the towers themselves, but huge amounts of heat and energy are lost. Generator-the turbine is linked by an axle to a generator, so the generator spins around with the turbine blades. As it spins, the generator uses the kinetic energy from the turbine to make electricity. Electricity cables-the electricity travels out of the generator to a transformer nearby for the next step distribution of energy. Step-up transformer-electricity loses some of its energy as it travels down wire cables, but high-voltage electricity loses less energy than low-voltage electricity. So the electricity generated in the plant is stepped-up (boosted) to a very high voltage as it leaves the power plant. Pylons-Hugh metal towers carry electricity at extremely high voltages, along overhead cables, to wherever it is needed. Step-down transformer-once the electricity reaches its destination, another transformer converts the electricity back to a lower voltage safe for homes to use [1], [6], [7], [8].

III. CALCULATION

The section indicates the Hydrogen pressure for ideal case for the operation of the turbine optimum. In the calculation we assume that, 1 bar = 1 kg for 140 bar pressure is approximately available from 140 Kg from Hydrogen cylinder. At the same time the because of at the normal temperature of 273 °K, we are pressurized the atom and hydrogen is the ideal gas, for that the pressure and weight will same.

The pressure on the each blade of the turbine is calculated as shown below:

PV = n*R*T

Where, P = Pressure

V = Volume $(cm)^3$

n = Mole

R = Constant (8.314)

T = Temperature (273 °K)

Moreover, for the proposed prototype the weight of the blade is 160 kg of turbine have the 24 Arcs. Taking the same into the consideration, the values of the mole and the pressure obtained are:

$$\text{Mole} = \frac{weight}{No.\ of\ Arc}$$

$$= \frac{160}{24}$$

$$\text{Mole} = 6.66$$

$$\text{Mole} \equiv 6 \text{ (approximately)}$$

$$P = \frac{n*R*T}{V}$$

$$= \frac{6*(8.314*273)}{100}$$

$$P = 136.18 \text{ bar}$$

In hydrocarbon maximum energy can be obtained from the naphthalene. If one can separate Hydrogen from naphthalene, the maximum energy can be obtained. The Naphthalene Structure is shown in fig.1. For separation of hydrogen the pressure of 136 bar is applied on turbine blade then

$$\text{Speed} = \frac{Pressure}{blades}$$

$$= \frac{136}{24}$$

$$= 6 \text{ rpm}$$

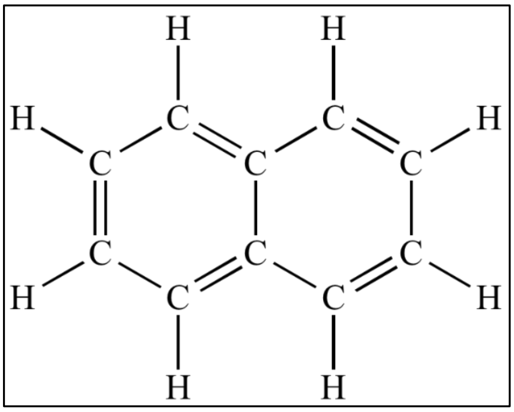

Fig. 1: Naphthalene Structure [5].

Moreover for Naphthalene At 80˚ C temperature the Production = 9.9, because 80˚-140˚ Separates the naphthalene and spilt Heat from it. So that from which the energy released by one Atom cab be calculated.

For 1 atom energy $=\frac{136}{9.9}$. Hence one atom energy is equal to 13.73

IV. RESULTS

For proposed Hybrid Hydrogen Power Plant, because the energy conversion in fuel cells is accomplished in a single direct conversion process, much higher efficiencies are possible than with conventional electricity generation by means of steam turbines which involve three energy conversion processes. In the overall phase the Chemical Energy is converted into the Electrical Energy, while in the first phase the Gas Turbine converts the Chemical Energy in to Heat and subsequently into the Mechanical Energy. The later on with Generators the Mechanical Energy is converted into the Electrical Energy. Since the fuel cell energy conversion is a chemical process, the maximum efficiency is not determined by Carnot's Law which applies to heat engines. The energy released by a chemical reaction is determined by the change in Gibbs free energy. For the chemical reactions involved in fuel cells the maximum theoretical efficiency is over 85% which is between two and three times the typical efficiency of a heat engine. The output voltage of a fuel cell falls as the current drawn from it increases. The net effect of this is that the efficiency also drops as the power drawn from the cell increases so that the efficiency is almost proportional to the output voltage. The typical operating efficiency of a fuel cell running at 0.7 Volts is about 50%. This means that 50% of the energy content of the hydrogen input is converted into electrical energy; while the remaining 50% will be dissipated as heat or lost through incomplete oxidation within the cells. The waste heat from the fuel cell electricity generating process can be used in combined heat and power (CHP) applications to provide local heating and thus improve the overall energy utilization efficiency of the Hydrogen fuel. This is particularly attractive for high temperature fuel cell systems.

V. CONCLUSION

The hydrogen infrastructure is not necessary for the proposed hybrid hydrogen power plant. A low fossil CO_2 emission in the environment can be made through central power production combined with CO_2 capture and sequestration, which encourage the areas like greenhouse effect and carbon foot print. Moreover, the applications of the proposed hybrid hydrogen power plant like: in the transportation sector the electricity can be supplied by biofuels in hybrid vehicles, with proposed the earth's tenth most abundant element and is the most lavish element in the universe having availability in vast from the World's oceans. The proposed plant produces neat & clean energy, which is also invisible, neutral, and non-toxic. Also it can be used in fuel cells to generate electricity-a need looking from the future prospective.

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