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Using Smart Grid for Efficient Utilization of Biomass based Fuels: Scope and Challenges

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***Abstract*— Biomass based fuels, unlike some of other sources of renewable energy, are sustainable and flexible in use without disturbing the environment. Several techniques to convert biomass from different sources have been developed. Techniques for efficient utilization of energy in general have been developed but for biomass based fuels the matter is much complex due to wide geographical and climatic distribution of feedstock. The points of utilization are also spread over large areas with varying demands and terrains. Distributed combined heat and power (CHP) generation has great potential for these fuels. Smart Grid can be deployed to solve techno-economic and other problems for sustainable and efficient utilization of biomass based fuels.**

Keywords*— *renewable energy; energy efficiency; smart grid; biomass; biofuels; sustainability

I. INTRODUCTION

Industrial revolution over past two centuries and population explosion created demand for unprecedented amounts of energy (Fig. 1). Fossil fuels like coal and oil have been used for generating heat and electricity to meet out this huge demand. In a very brief period the emissions like green house gases (GHG) from these fuels have very adverse effect on the environment, which nature took billions of years to create. Climatic changes in the form of erratic rain patterns, hurricanes and temperature variations of air, land mass and water bodies played havoc with the life on the planet. Fossil fuels, as they take very long time for developing under the layers of earth, cannot be replenished in a short time on demand. So, they are not sustainable and will become costlier over the time due to scarcity with growing demand and finally beyond a time will cease to exist at all. An alternative in the form of nuclear energy has been developed but there are several accidents involving dangerous and long lasting radioactive emissions.

II. BIOMASS BASED FUELS

A. Sources of Renewable Energy

All these factors lead to develop renewable forms of energy like hydro, solar, wind, biomass, geothermal, tidal and many more, which are economical, sustainable and non-polluting in nature. However, except biomass based fuels, they have major problem of storage and cannot be used directly for some important purposes like transportation [1].

Fig. 1. Energy consumption in the United States, China, and India, (quadrillion Btu)

On the other hand, biomass based fuels, in solid, liquid and gaseous forms are not only sustainable but unlike most of other renewable forms of energy, they can be used at the point of production, stored in fuel tanks and transported to the remote point of use [2]. Major sources of biomass are agricultural products which are grown year after years in environment friendly manner through crop cycles (Fig. 2).

B. Biomass based Fuels

Several techniques have been developed so far to convert biomass into useful fuels. These conversion processes are either Thermal-Catalytic or Biological in nature like fermentation using enzymes and micro-organisms.

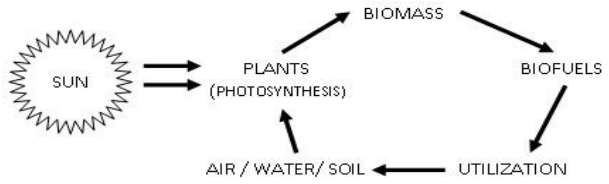

Fig. 2. Solar energy is stored into biomass by photosynthesis and utilized through carbon cycle

First generation biomass based fuels are obtained from oils and sugars present in agricultural and forest products and residue. Municipal and industrial wastes are other good sources of feedstock. Several studies related to technical, economical, social and environmental aspects have been carried out by the researchers. The important fuels in this category are ethanol, methane and bio-diesel.

The aim of researchers has been to develop fuels from the agricultural products growing on non-arable lands. However, economic considerations attracted farmers to grow crops for fuel in place of the food leading to crisis in several parts of the world, especially in the underdeveloped and developing communities, due to reduced food production and subsequent increase in price.

Second generation biomass based fuels are extracted from inedible lignocellulosic parts of crops, forest residue and wastes from industries based on agricultural and forest products. They can be obtained for ever as sustainable feedstock without disturbing the ecology of the agricultural land and forests. Several techniques, like flash pyrolysis and laser-induced processes, have been developed to produce biomass based fuels like 'Fischer-Tropsch diesel'. Research is still continued to make these processes efficient, environment friendly and economically viable.

C. Utilization of Biomass based fuels

Biomass based fuels are being used in domestic, commercial and industrial sectors for producing heat, light and electricity [3] as shown in Table I. Enormous amount of work to develop technologies for efficient utilization of energy in general have been done, but for efficient utilization of biomass based fuels to generate electricity, the matter is much complex due to wide and varying geographical and climatic distribution of the feedstock and consumers [4,5].

TABLE I.
TECHNOLOGICAL FACTORS IN UTILIZATION OF BIOMASS BASED FUELS

<table>
<tr><th>Physical Forms (for storage/ transportation</th><th>Utilization Sectors</th><th>Application Areas</th><th colspan="3">Energy Conversions</th></tr>
<tr><td rowspan="2">Solid</td><td rowspan="3">Domestic</td><td>Light</td><td colspan="3" rowspan="2">Direct</td></tr>
<tr><td>Heat</td></tr>
<tr><td rowspan="3">Liquid</td><td>Telecommunication</td><td colspan="3">Electricity Generation</td></tr>
<tr><td>Commercial</td><td>Transport</td><td rowspan="2">Centralized</td><td colspan="2">Distributed</td></tr>
<tr><td>Gas</td><td>Industrial</td><td>Machinery</td><td>Off-grid</td><td>Grid-tied</td></tr>
</table>

The points of utilization are also spread around the globe with varying demand and terrain. Some other independent and interdependent technical, economical, social and cultural factors are also to be taken into consideration for their appropriate use (Table 1). However, Electricity being the most widely used form of energy, needs special attention for the generation, distribution and utilization in most efficient way [6].

III. SMART GRIDS

A. Distributed Power Generation

Electricity generation using biomass based fuels is intermittent in nature due to varying climate and availability of feedstock at a particular geographical location [7]. For uninterrupted and reliable power supply, a mechanism to compensate for the fluctuations in generation is required. Connecting the biomass based generation plant to a power grid is one of the basic solutions.

However, conventional or standard power grid system is not a very efficient way for the best utilization of renewable power generation units. The reason is the small capacity of the plants and their distributed nature of the location and operation. At times, the plant may supply sufficient electricity to the covered area but during low or no power generation periods may need power from other generation plants. At times of low demands e.g. night or abundance of feedstock during favorable crop season, surplus energy generated may be supplied to other users. Therefore a biomass based power plant can be a part of a local micro-grid which may further be the part of another small/ large or even national grid. This form of multilevel power generation and distribution is efficient but complex and not feasible in a conventional power grid system. However, the problem can be solved by using a flexible power transmission and distribution system [8,9].

B. Basics of Smart Grid System

Smart grid system in simplest terms is a bi-directional power network [10]. It is an integration of conventional power transmission and distribution technology with electronic monitoring and control systems and digital data networks (Fig. 3). Supervisory control and data acquisition (SCADA) as monitoring and control and information and communication technology (ICT) are well developed building blocks of the system.

Two way flow of power between generation plants, the grid and points of utilization is monitored and controlled. The data collected at different points and levels flow seamlessly from one end to another of the system. Smart meters with network communication capabilities are the most important component of the smart grid. They provide means for dual-tariff management which is essential for small distributed biomass based power plants and other power plants based on renewable energy sources like, solar and wind. The data communication utilizes power line communication (PLC) or wireless communication systems.

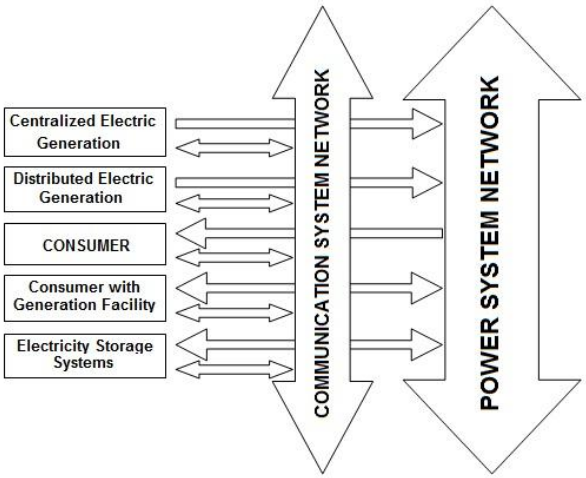

Fig. 3. Concept of Smart Grid

Reliability and security of data networks is an important factor in smooth and efficient operation of the grid system. Modern power electronic devices are reliable and energy efficient solutions for power control systems involving regulation of amplitude, load, phase and frequencies and fault signals. Micro-power, low-cost embedded processors provide cost effective means for integrating sensors and interfacing power controls. The data communication networks are very efficient and reliable and are used in some of the critical operations like high speed railway systems [11-13]. A local mishap or fault can be isolated and remedied at very fast rate providing resiliency to the system. Therefore, operation and maintenance of the smart grid is automated, safe, reliable and economical.

IV. ISSUES AND OPPORTUNITIES

A. Reliability and Fault Tolerance

The grid should be resilient to the sudden changes due to load and fault transients along the system. Real-time monitoring and control software can manage this function much better than the classical grid and make appropriate adjustments at local node level with minimal disturbance.

B. Robustness

Reliability of the grid depends much on the quality of hardware and software parts of the system. Most of the existing technologies for smart grid are well proven and time tested.

C. Standards

To reduce downtime of installation and easy integration, there must be standards for all vital parameters related to software and hardware in the system. Independent and government organizations across the world are working on developing standards and making suitable modifications to proposed ones. This will ensure smooth transition and interaction between grids of different configurations and capacities without problems of interface mismatches and compatibility issues.

D. Adoption of Technology

Smart grid is a mix of existing and emerging state of the art innovations and technologies relating to several branches of science and engineering. There must be provision for upgrading the system using new and better techniques and devices as and when they are available.

E. Security and privacy

Breach of the system by natural or deliberate attempts must be made secure to safeguard the interests of all stakeholders. The data of technical and financial nature needs to be protected for the efficient and reliable operation of the grid. Advancements in the field of cyber-security for research, defense and commercial applications, with suitable modifications, may be utilized for safe operation of smart grid.

F. Business model

For the successful operation of the smart grid, a careful study is required about financial aspects of the system. A proper business model is to be developed for economic management and maintenance of the grid. The electricity generation from biomass based fuel has the potential for providing sustainable energy supply at economical scale with added benefit of environmental protection [14-16]. Therefore distributed generation with availability of feedstock at low cost and available carbon credits may lead to a very attractive business model for the developers.

CONCLUSIONS

Smart grid systems may be deployed for efficient utilization of electricity generation by using biomass based fuels. These fuels being renewable source of energy may play a very vital role in sustainability of the environment and development. With the progress in electronics and computer technology, the smart grid will be more reliable and economical in operation and maintenance.

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