ISSN 2004-2965 Energy Proceedings, Vol. 20, 2021

International Conference on Applied Energy 2021
Nov. 29 - Dec. 5, 2021, Thailand/Virtual
Paper ID: 794

Future Industrial Energy Systems Design and Demand Side Management

Hakan Gul [1], Xiaonan Wang [1*]

1 Department of Chemical Engineering, Tsinghua University, Beijing 100084, China

ABSTRACT

Today, threats arise in many respects due to the interruption of the carbon cycle, and these threats endanger the future of human and earth. The major reason is the fossil fuels consumption in energy production and the inefficient use of energy and sources. In this study, in addition to supporting the integration of renewable energy sources (RES), which will be increased for global sustainable development and targets of net-zero emissions, especially the 2060 carbon neutral targets of China which is the production center of the world, the main motivations are reducing the carbon emissions that occur in energy production and industrial productions, increasing the efficiency of energy consumption and to put the carbon cycle on track and to eliminate global disasters especially climate change and extreme weathers.

In this study, it is aimed to achieve carbon neutralization by adapting industrial productions to demand side management (DSM) applications in the determined industry with fully autonomous dynamic production lines equipped with industrial internet of things (IIoT) and automation technologies in accordance with Industry 4.0 standards, while making full use of RES and carbon capture, utilization, and storage (CCUS) technologies.

Keywords: carbon capture utilization and storage demand side management, industry 4.0, renewable energy sources, renewable methanol and ammonia

NOMENCLATURE

Abbreviations	
DR	Demand Response
DSM	Demand Side Management
CO2	Carbon Dioxide
CCUS	Carbon Capture, Utilization, and Storage
EE	Energy Efficiency
IIoT	Industrial Internet of Things
LS	Load Shifting
PC	Peak Clipping
PP	Power Plants
RES	Renewable Energy Sources
SLG	Strategic Load Growth
VF	Valley Filling

1. INTRODUCTION

Today, fossil fuels constitute the majority of electricity energy production sources both in the world [1] and in China [2]. The breaks in the carbon cycle caused by the high-speed consumption of fossil fuels for many years show that fossil fuels have lost sustainability. RES, on the other hand, contributes to reducing carbon emissions and offers sustainable sources. However, it is not possible to switch most of these sources from fossil fuels to renewable clean energy sources under the current conditions, because the increasing fluctuation in renewable energy production and demand of energy requires new flexibility options within the electricity system in order to guarantee security of supply-demand.

In order to increase the use of RES, consumption should be shifted to the energy production time period of these energy sources and the energy obtained from RES should be stored and managed smartly.

Although it is aimed to increase the share of RES in energy production and DSM applications are used, it is not possible to reach complete neutralization while

Selection and peer-review under responsibility of the scientific committee of the 13th Int. Conf. on Applied Energy (ICAE2021).

making great progress in reducing these carbon emissions. It is difficult to reach carbon neutrality due to both the continuing need for fossil fuel sourced power plants (PP) and the carbon emissions that occur during the production phase in the industry. This study incorporates CCUS technologies into the system in order to achieve carbon neutralization or even to progress to carbon negative.

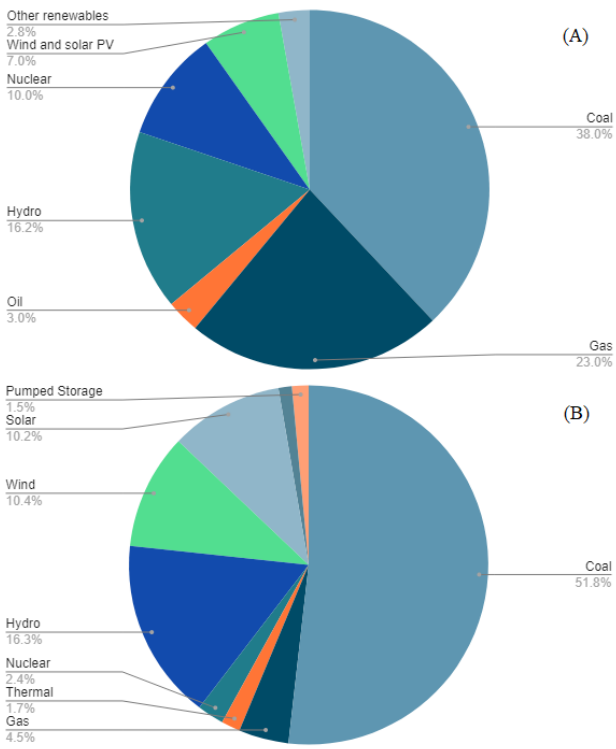

Fig. 1. Power generation mix of (A) 2018 World [1], and (B) 2019 China [2].

While DSM methods balance the electrical energy demand in the industry according to the energy production potential in the RES, long-term balancing in energy will be achieved with CCUS technology and the ammonia, hydrogen and methanol industry, which is the main study area of the research.

2. METHODOLOGY

2.1 Demand Side Management

DSM covers many direct or indirect methods of changing consumption usage profiles according to the benefits of the network. These methods consist of demand response (DR), energy efficiency (EE) and strategic load growth (SLG) objectives. In the modern definition DR programs consist of peak clipping (PC), load shifting (LS), valley filling (VF) and flexible load shape (FLS) [3].

While PC aims to directly decrease peak demands, LS which is the combination of PC and VF aims to achieve this reduction by spreading it to other time zones. Their main motivation is to reduce the installed power calculated according to peak demands. By taking advantage of its low average cost, VF aims to increase the load during off-peak periods, thus reducing the costs of switching on and off the plants in active production and consuming the residual load. FLS targets the optimum supply conditions according to the forecasted various utility programs and plans, while the consumer is offered options with various incentives. EE aims to reduce all energy load thanks to the developing technology without disturbing the industrial comfort. The SLG's goal is to increase the overall load level due to using new electricity technologies with replacing electricity with other fuels. [4]

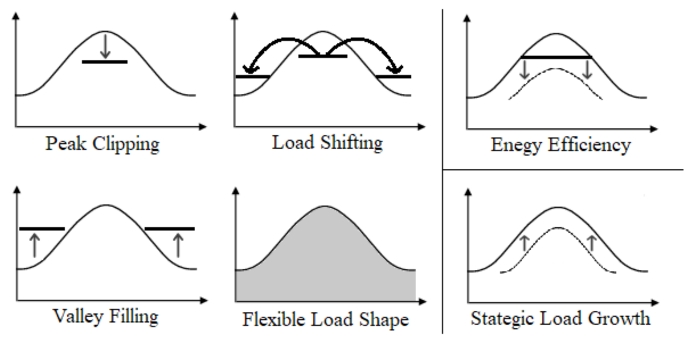

Fig. 2. Load shape objectives in DSM [3]

2.2 Energy-Production Management in Industries

2.2.1 Industrial Internet of Things

IIoT, which consists of cloud connected devices and the intelligent platforms that process the big data, provides end to end real time production transparency and improves industry efficiency. Thanks to the energy consumption data from the IIoT, the job can be planned by minimizing the energy consumption costs of the production schedule [5]. Ref [6] identifies the advantages of IIoT as follows: using real energy data to increase EE for production management, adjusting energy consumption accordingly DR programs and using renewable energy efficiently with adjusting production schedule based on the energy production period. IIoT uses forecasting tools with big data and analytics to determine pricing, capacity requirements, and customer demand [7].

2.2.2 Industry 4.0

Industry 4.0 is a revolutionary development based on IIoT, digitalization, machine learning and artificial intelligence, where communication is at the forefront, beyond automation and robotics [8]. Ref [9] explains the benefits of Industry 4.0 in EE as follows: scheduling manufacturing process, creating better logistic routes, using enhanced warehousing methods, streamlining material and products handling, adjusting temperatures around the manufacturing areas, faster detection of faults, better maintenance procedures and schedules, and better integration between the building and manufacturing facilities.

2.3 Renewable Energy Sources

There can be imbalances and discontinuities arising from the production supply of renewable energy, which is carbon neutral, which is listed as solar energy, wind energy, wave energy, geothermal energy, hydraulic energy, and biomass energy, which is independent of raw materials and people, but depends on weather and nature conditions.

Important methods of managing the outage and fluctuation in RES are to integrate different RES into the system and take advantage of the fact that simultaneous weather conditions can differ from one location to another by spreading the variable renewable energy distribution over a wide geographical area [10].

2.4 Renewable Methanol and Ammonia

In the RES dominant model in energy production, a transition towards electricity is planned as the dominant energy carrier in all sectors. Moreover, RES is used as a raw material for the production of methanol and ammonia in the hydrogen industry, ultimately reducing carbon emissions in their production [11].

2.5 Carbon Capture, Utilization, and Storage

While the improvements in reducing carbon emissions are achieved with the transition to less carbon-intensive fuels and RES, another improvement can be the capturing of carbon dioxide (CO2) from the industrial environment and energy production sources and its use as a raw material in industries or its long-term storage [12].

Industrial uses for CO2 were the production of urea and methanol, chemical and biological processes in which CO2 is a reactant, as well as various technological applications that use CO2 directly. In industries, predominantly high-concentration sources are ammonia and hydrogen production facilities, and these facilities also have the lowest unit capture costs [12, 13].

3. APPLICATION AREA

In this study, the application and research area, it has chosen ammonia, hydrogen and methanol plants in the industry, and has chosen solar PP and coal PP as the electrical energy source. The industry also includes air separation units and CCUS plants.

While ammonia and hydrogen plants were chosen due to the high carbon capture rate and low carbon capture cost, methanol plants were chosen for the use

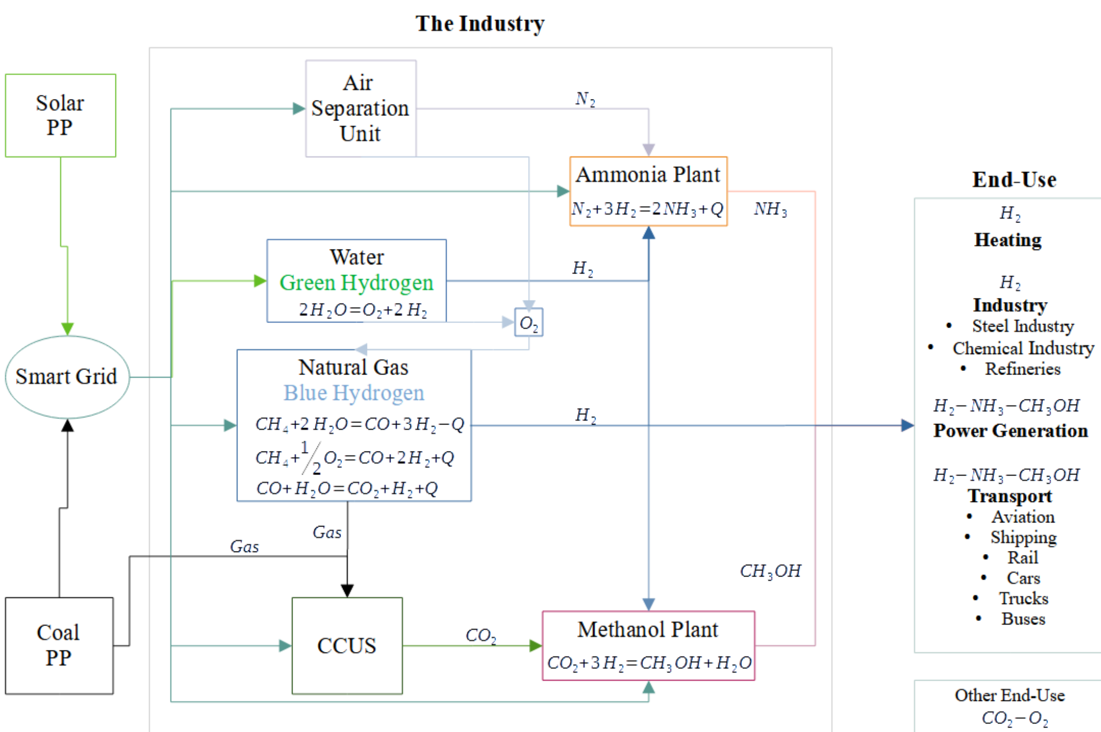

Fig. 3. Application Area

of CO_2 obtained. Since the products produced by all three plants are sources of energy raw materials, it will give a different direction to DSM methods.

By choosing solar PP, whose share in all electricity generation is predicted to be dominant in the future, it is aimed to fully benefit from renewable energy by using DSM methods effectively and by the fact that the products in this industry are energy carriers. Coal PP was chosen to ensure continuity in electrical energy supply and production in the industry.

Hydrogen production is divided into green hydrogen and blue hydrogen. While green hydrogen is produced from renewable energy and water, blue hydrogen is produced from natural gas. Green hydrogen needs cheapness in energy, which is targeted with RES. In order to capture the carbon to be used in the production of methanol, the gases generated in blue hydrogen plants and coal PP will be used.

While this industry basically needs electrical energy, water, natural gas and air from the outside, it provides the hydrogen, nitrogen, CO_2 and oxygen it needs within itself. Its end products are used in heating, industry, energy production and transportation.

4. RESULTS AND DISCUSSION

Full capacity detailed production profiles of RES will be determined depending on environmental and natural conditions by using data science and forecasting methods.

By making use of Industry 4.0, energy consumption plans will be produced by making intraday, daily, weekly and monthly production plans in the industry in accordance with DSM policies. As Industry 4.0 advances, EE will reach its peak.

In this system, with DSM methods, while the short-term electricity demand in the industry is balanced, minimization of carbon emission is aimed, while the remaining CO_2 is collected by CCUS technology, it is aimed to completely eliminate the emission. The CO_2 obtained can be used directly within the industry itself, and the remaining carbon can be transferred to other industries as raw materials or stored. While this industry aims to zero carbon emissions with DSM methods and CCUS technology, it is aimed to create a carbon negative effect by reducing overall emissions as an alternative to fossil fuels as a result of the products it produces.

5. CONCLUSION

This study presents a pre-methodology for facilitating the integration of more RES to reduce carbon emissions. With the help of big data, it will be possible to shape energy demands through the use of evolving technologies. Thus, while benefiting from renewable energy is increased, it is planned to reduce carbon emissions by more than one-fold with various developments.

REFERENCE

[1] IEA (2019), World Energy Outlook 2019, IEA, Paris https://www.iea.org/reports/world-energy-outlook-2019

[2] 2019 detailed ELECTRICITY Statistics (update of Jan 2021). China Energy Portal | 中国能源门户. (2021, February 26). Retrieved September 21, 2021, from https://chinaenergyportal.org/en/2019-detailed-electricity-statistics-update-of-jan-2021/.

[3] Chuang, A. S., & Gellings, C. W. (2008). Demand-side integration in a restructured electric power industry. CIGRE, number Paper C6-105, Session.

[4] Rabl, V. A., & Gellings, C. W. (1988). The concept of demand-side management. In Demand-Side Management and Electricity End-Use Efficiency (pp. 99-112). Springer, Dordrecht.

[5] Shrouf, F., Ordieres-Meré, J., García-Sánchez, A., & Ortega-Mier, M. (2014). Optimizing the production scheduling of a single machine to minimize total energy consumption costs. Journal of Cleaner Production, 67, 197-207.

[6] Shrouf, F., & Miragliotta, G. (2015). Energy management based on Internet of Things: practices and framework for adoption in production management. Journal of Cleaner Production, 100, 235-246.

[7] Lopez Research. (2014). Building smarter manufacturing with the Internet of Things (IoT).

[8] Munirathinam, S. (2020). Industry 4.0: Industrial internet of things (IIOT). In Advances in computers (Vol. 117, No. 1, pp. 129-164). Elsevier.

[9] Mohamed, N., Al-Jaroodi, J., & Lazarova-Molnar, S. (2019). Leveraging the capabilities of industry 4.0 for improving energy efficiency in smart factories. IEEE Access, 7, 18008-18020.

[10] Zeyringer, M., Price, J., Fais, B., Li, P. H., & Sharp, E. (2018). Designing low-carbon power systems for Great Britain in 2050 that are robust to the spatiotemporal and inter-annual variability of weather. Nature Energy, 3(5), 395-403.

[11] Möst, D., Schreiber, S., Herbst, A., Jakob, M., Martino, A., & Poganietz, W. R. (2021). The Future European Energy System: Renewable Energy, Flexibility Options and Technological Progress (p. 309). Springer Nature.

[12] Metz, B., Davidson, O., & De Coninck, H. (Eds.). (2005). Carbon dioxide capture and storage: special report of the intergovernmental panel on climate change. Cambridge University Press.

[13] National Petroleum Council. (2019). Meeting the Dual Challenge: A Roadmap to At-Scale Deployment of Carbon Capture, Use, and Storage.