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How to balance the industrial customers' resources requirements while maintaining energy efficiency?

Jingyi Zhu[a], Yang Zhang[b,*]

[a] Swan College,Central South University of Forestry and Technology, Changsha, 410211,Hunan,China
[b] Hunan New Think Tank, Hunan University of Technology and Business, Changsha, 410205,Hunan,China

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ABSTRACT

One of the most important challenges facing the optimal management of power resources for industrial customers is considering the latest available technologies for this purpose. In this regard, this article investigates the most important technologies and methods available in this field and tries to maintain the energy efficiency at a suitable level by presenting a knowledge-oriented approach. One of the most important technologies used in this field is demand response, which provides an opportunity for consumers to provide an appropriate response to energy at various price rates by reducing or changing electricity consumption in peak load. In addition, the emergence of different renewable energy sources such as solar and wind in recent years has created a suitable opportunity for the participation of the majority of industrial and household consumers and as a result has increased social awareness in this field. The above items are investigated and discussed one by one in this paper and the impact of each of them on meeting the needs of industrial customers is assessed. In the end, it is tried to present a model to show how to optimally use these resources in scheduling from the social, economic and technical point of view.

Introduction

In recent years, the issue of industrial electrical consumers has become one of the challenges facing human societies. On the one hand, with the industrial revolution and the emergence of new technologies, we are encountering the improvement of the life quality in various dimensions, which itself is caused by the increasing access of people to sustainable energy sources (Dabbous, A. & Tarhini, A., 2021). On the other hand, this access has caused us to witness the emergence of large industrial factories and companies every day, which, in addition to the countless benefits they provide for us, also had many disadvantages with them. One of the most important challenges and disadvantages for large industrial consumers is the increase in excessive use of fossil fuels and becoming very large consumers of energy in different sectors. At first glance, very high economic costs caused by energy supply have caused the price of goods and liquids made from petroleum products to increase, which in turn weakens the quality of life of human beings (Kwangsawad, A. & Jattamart, A., 2022). In the second view, from the social point of view, it can be seen that along with the increase in the number of industrial consumers, the social class distance has also increased and there are large social gaps in the society. In the last point of view, the technical problems caused by this increase in energy consumption can also lead to the complexity of the power grid, which requires new planning and management methods to solve these problems (Franco, M. & Pinho, C., 2019). In this regard, it can be seen that in recent years, researchers have been able to provide new methods and technologies as alternative solutions to provide as much balance between production and consumption in the industrial sector as possible. In the following, we describe some of the most important upcoming technologies.

One of the most important technologies available in this field is renewable energy sources (Ha, L. T. & Thanh, T. T., 2022), which tries to bring energy production sources closer to consumers in addition to reducing energy losses in distribution lines and helping to increase consumers' awareness of the production method. In fact, from the point of view of psychology, this issue makes all the people in the areas that check and think of the difficulties of energy production indirectly. Based on the statistics in this field, it can be seen that the general public saves energy in optimal consumption when they see the difficulties and challenges ahead of energy production (Shahzad, Qu, Rehman & Zafar, 2022). This in itself makes the activities of large industries to be limited as much as possible in parallel with the

* Corresponding author.
E-mail address: 2365@hutb.edu.cn (Y. Zhang).

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production energy. In other words, social awareness resulting from renewable energy sources will indirectly increase the amount of support for industrialists and large industrial producers in the long term. This issue can greatly improve the limitations of fossil fuel energy sources and reduce its technical and economic costs. Also, the data and statistics show that by reducing the pollution caused by less energy consumption, the pollution in the environment and forests can be reduced to an acceptable level. Another important and effective method in this field that can be examined from a social point of view is the issue of accountability (Gandiglio et al., 2022). This problem has been considered by the researchers as social activism so that it can help to increase efficiency by involving more household and industrial consumers in the processes of exploiting energy resources. This issue shows its importance when the amount of production and consumption during the day and night is compared to the installed capacity of a power plant. As a result, it will be seen that residential and industrial loads with this number of consumption hours from peak load to low load can be of great help in eliminating capacity shortages in the power plant sector. What is clear is that this method can be used as an analog technique to increase the participation of consumers in different parts of the world. In recent researches, it has been shown that not only the use of the demand response leads to an increase in efficiency, but it also helps to reduce costs and increase social awareness (Perez-Antolin, Schuhmann, Palma & Ventosa, 2022). The point to consider here is that the greater the participation of industrial and residential consumers in the final consumer sector, the less the need for future investments will be. In addition, the improvement of the energy consumption pattern can lead to the improvement of network reliability with the help of this set of measures that are carried out in the demand response section. As the last and one of the most important resources used for the optimal use of energy, we can mention energy storage batteries (Babatunde, Munda & Hamam, 2022). In recent years, they have experienced great progress in storage. From a technical point of view, the use of energy storage devices along with renewable energy sources has caused the hours of non-production of energy to be compensated by these sources, and as a result, they are used as a stable and reliable source. Although good progress has been made in this field in recent years, statistics show that energy storage efficiency and usage are still low, which requires more investments and planning in this area (Khanahmadi, Mozaffarilegha, Manthouri & Ghaffarpour, 2021).

In this context, it should be noted that storage devices are not only batteries, but storage devices can also play an important role in the thermal and storage parts of fuel cells and thus lead to an increase in efficiency. In this article, the effectiveness of each of the factors mentioned above in order to increase the balance in energy production and consumption in industrial sectors will be investigated and the most important influencing factors in these technologies will be introduced. After the precise definition and identification of the technologies, we have tried to examine the accuracy and quality of movement of these methods with a simple but practical example. Certainly, considering the fact that we are always witnessing an increase in residential consumers along with large industrial consumers, it is necessary to include both industrial and residential areas in the surveys. In order to solve the upcoming problem, the methods of evolutionary algorithms will be used, which have been well accepted by the engineering community in recent years. The proposed method is based on genetic algorithms, which tries to simulate a random and optimal process by simulating the process of transferring chromosomes and genes from parents to children. The results of this research show that the simultaneous use of renewable energy source technologies and the issue of demand response and energy storage devices can lead to an increase in energy efficiency in different sectors. In addition, as mentioned, each of these three techniques and strategies has been used in the final consumer section, which will increase social and psychological awareness among them.

Demand response management programs

Demand response management is a strategic program which can help much to increase the social awareness about the ways that people can help to mitigate the unwanted effects of energy usage in the modern life. In recent years, after the privatization and competitiveness of the electricity industry, one of the important factors in the field of energy systems exploitation is the demand response. In fact, parallel to the increase in the value of this problem and its direct and indirect effects on human social life and the importance of preserving the environment, the need for this strategy is felt more and more. As a result, in order to optimize the management of large electricity consumers, we need management tools on the consumption side and on the part of final consumers. According to the definition, demand response is the direct participation of consumers in energy planning in order to reduce the desired amount of consumption in the industrial and residential sector and to improve the energy consumption pattern as much as possible. The aim of this program is to reduce the difference between peak load and low load in different hours of the day and in different seasons, which can ultimately lead to an increase in the balance between consumption and production. Certainly, from the social point of view, this means preventing the wastage of social capital and also using this capital in other parts of human life (Saboori, H. & Jadid, S., 2022).

Therefore, this program can be mentioned as one of the strategic programs in different economic, social, political and cultural sectors. Smart networks can encourage consumers to modify their consumption pattern by using accurate hourly consumption information, including the price of electricity at different hours throughout the day and night, and this process can be done automatically. In this regard, it is necessary to get acquainted with the problems that preceded the spirit of these plans so that we can fully focus on the spirit of successful implementation of these strategies. For example, in order to use demand response program, we need to use smart metering systems in all heavy consumers. It is one of the big industrial consumers of the steel industry, which can consume up to twice as much energy during non-peak hours. In case, by properly distributing his workforce during the day, he can properly participate in demand response planning and reduce costs and emissions (Liu, Chen, Yang & Shan, 2021). As it has been shown in recent researches, the demand response is not only economical and technical, but also very important from the social point of view. This issue has not been far from the eyes of researchers in recent years, and some of them have considered it in a decisive way and expressed the psychological effects of this program well. For example, by encouraging large consumers to participate in demand response planning, it is possible to reduce the amount of consumption in a proper way and to inform people and consumers in this field. When consumers become familiar with demand response planning, they gain a very good understanding of energy consumption, which can be not only suitable from an economic point of view, but also can reduce emissions caused by high consumption from a social point of view. In addition, this awareness among the general public has made them facilitate their consumption pattern in a proper way. It should be noted that in recent years, a process of culture formation in various urban and rural areas has been well considered so that the majority of civilized societies are aware of the importance of energy and saving in this area for future generations (Elmorshedy, Elkadeem, Kotb, Taha & Mazzeo, 2021). Technically, demand response programs can be examined in two types of shiftable and curtailable industrial loads, within hourly, daily or weekly programs. In this article, this issue will be implemented on a small industrial grid and will show how the balance between consumption and generation will be investigated. Fig. 1 shows the average amount of energy consumption in different industrial sectors based on studies conducted on a part of China. As it can be

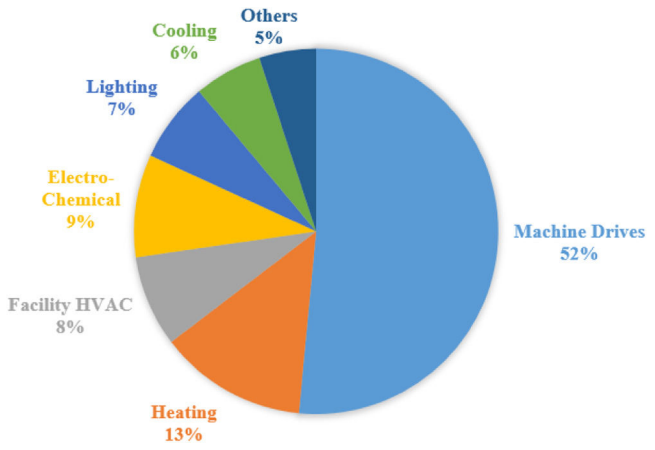


Fig. 1. Chart of Average Energy for a Sample Region in China.

seen, the highest amount of consumption belongs to machine drives, followed by heating and high voltage systems.

Renewable energy sources

Renewable energy sources are one of the most important sources of energy production in human life in the years after 2000 in the world. One of the most important features of renewable energy sources is their clean nature and compatibility with nature, which makes them a suitable alternative to fossil fuels. In this regard, various types of natural energy, including wind energy, solar energy and biomass can be extracted by these sources, which can be used according to the geographical nature of the investigated area. For example, in desert areas, there is a very good potential for using solar energy sources, although the efficiency of these sources decreases with the increase in temperature. However, it is a very suitable alternative for remote areas (Engelhardt, Zepter, Gabderakhmanova & Marinelli, 2022). In areas with monsoon winds, the ideas of using wind energy sources can be explored in different ways. Different types of renewable energy sources can be used in different regions in all countries. What is important is the social effects of these sources on the energy consumption performance of the people of each region. Based on the research conducted, when people see a practical wind renewable energy source near their place of residence, they are continuously exposed to the challenges facing energy production. Therefore, what is expected is that in the long term, the amount of energy consumption will decrease, and according to the approach of renewable energy sources, we can expect cleaner air and less pollution. Owners of agricultural lands and remote areas can access a significant part of their daily needs through these sources by using small renewable energies (Eghbali, Hakimi, Hasankhani, Derakhshan & Abdi, 2022). Some of the most important features of renewable energy sources are their clean nature, ease of installation and energy supply at the level of a single load of customers, improvement of the voltage profile and reduction of costs due to power losses in the lines. Due to the fact that renewable energy sources are installed on the distribution side, they can be discussed as small producers by reducing the need to transfer energy from the high voltage grid side. In Fig. 2, the rates of this ratio for different renewable energy sources in China are shown for a sample region. As it happens, water energy is at the top, followed by wind and solar energy. Of course, what is certain is that in the long term, the existence of new technologies can change the role of each of these sources and make them the first priority.

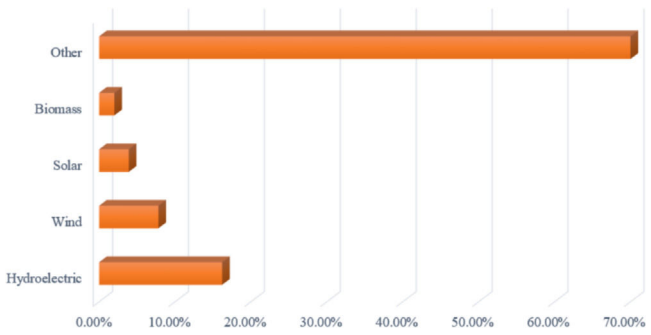


Fig. 2. Portion of renewable energy sources usage in china over 2022.

Battery storages

Another very suitable and powerful technology to deal with energy fluctuations in different hours is energy storage. According to the International Electrotechnical Commission, electric energy storage devices are one of the key technologies in the different areas. In fact, the basic need for energy storage devices is caused by a previous need that arises regarding renewable energy sources. Due to the fact that monsoons and sunlight vary at different hours, a storage device is necessary to dampen these fluctuations. In general, the three main roles of energy storage systems can be mentioned as reducing electrical costs, increasing the reliability of the power supply, and improving the quality of power. According to the technologies used in the large industries of the countries, it can be used in two modes, on-grid and off-grid. In addition, in parallel with fossil fuel energy sources, they can improve power and frequency fluctuations (Marocco, Ferrero, Martelli, Santarelli & Lanzini, 2021). It should be noted that energy storage can be considered in different types, including batteries, thermal storage, and hydrogen storage. The most important advantages of batteries can be pointed to high efficiency and low losses, high response speed and high storage density. Parallel to these advantages, the most important disadvantages of batteries can be mentioned by short life compared to other storage devices and dependence on environmental conditions and environmental pollution (Xu et al., 2022). Due to the fact that renewable energy sources are used in the distribution network sector, batteries should also be able to be used at this level. With the improvement and advancement of battery technology in recent years, it is possible to store energy in low-load hours and use it in high-load hours (Yang, Bremner, Menictas & Kay, 2022).

Simulation results

As mentioned earlier in the previous sections, in this section we will examine how to create a balance between renewable producers and batteries and large industrial consumers such as factories in a grid. For this purpose, we will use a test network (Baziar, A. & Kavousi-Fard, A., 2013). The investigated test network has different types of renewable energy sources, including wind and solar, as well as batteries. In addition, this network also considers fuel cell and micro turbine sources as fossil sources. Consumers include three residential, industrial and commercial networks, which are among the largest consumers of electricity in a network. For proper planning between these units, genetic algorithm is used. As it was said, the social effects resulting from the proper planning of the use of these batteries and renewable energy sources can be shown in economic and technical dimensions as well. In this section, an attempt is made to indirectly examine their social and technical effects by showing cost reduction methods. Fig. 3 shows a general outline of the test network under investigation. Fig. 4 shows the hourly wind turbine power, solar unit power, market price and load demand. As it can be

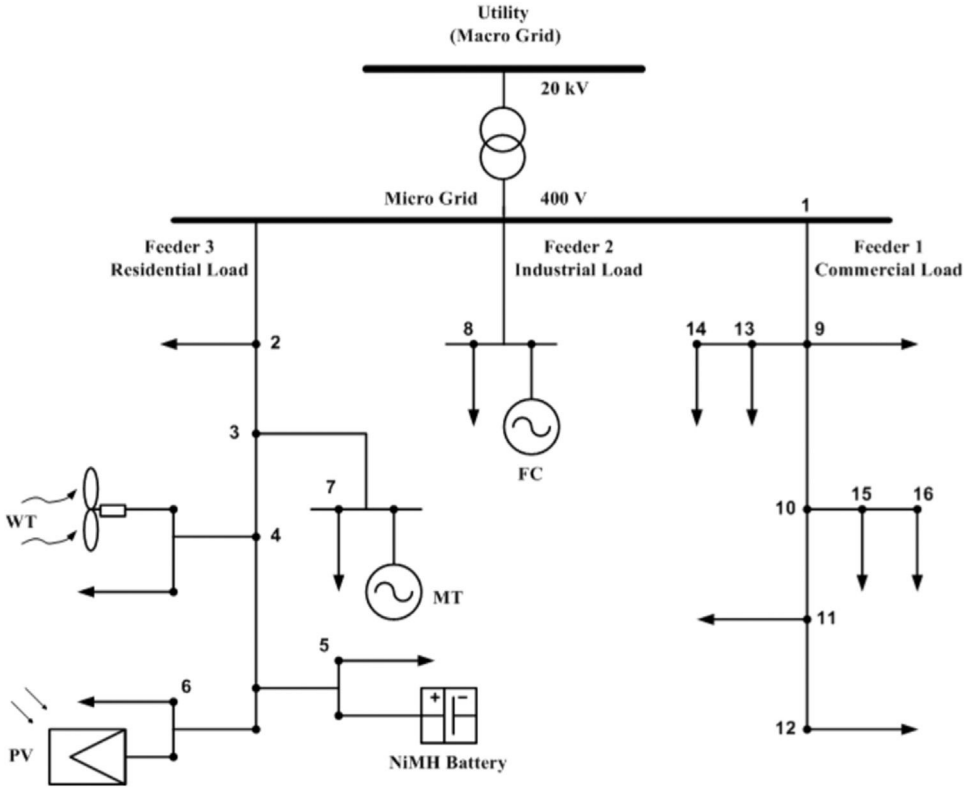
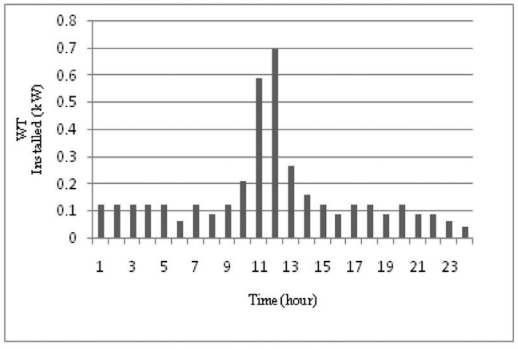
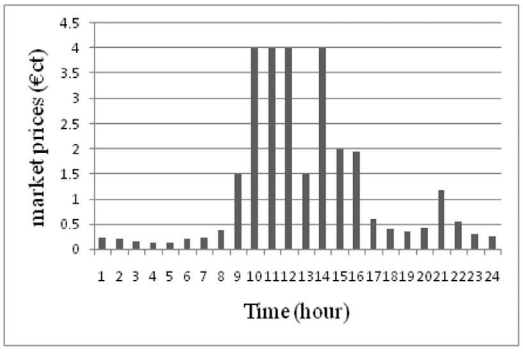


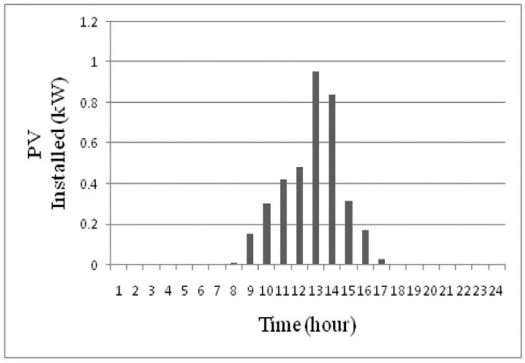
Fig. 3. The schematic diagram of the industrial test system and power suppliers.



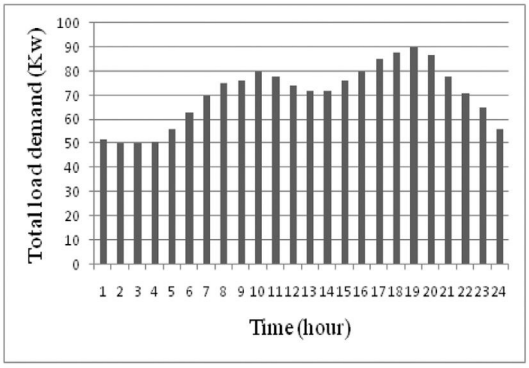
Wind turbine power value



Market price during the day



Solar unit power generation



Total load demand in the grid

Fig. 4. Predicted curve of the load demand, market price and solar unit and wind turbine power production.

Table 1
Characteristics of the renewable sources & the utility.

Type	Min Power (kW)	Max Power (kW)	Bid (€ct /kWh)	Start-up/Shut-down cost (€ct)
Microturbine	6	30	0.457	0.96
Fuel cell	3	30	0.294	1.65
Solar	0	25	2.584	0
Wind	0	15	1.073	0
Battery	−30	30	0.38	0
Grid	−30	30	–	–

seen from these figures, the solar unit and the wind unit are generating random power at different hours. This shows the necessity of the battery usage for the sake of the stability.

Table 1 shows the characteristics data of the power units including renewable and non-renewable types. As it can be seen from this figure, the renewable sources are non-dispatchable since when they are connected, they should produce power as much as they can. Battery is considered in a suitable size required by the renewable sources to keep the balance and reduce the costs.

As mentioned before, one of the most important tools for the optimal use of renewable energy sources and fossil resources is the optimization method. In this article, improved genetic algorithms are used, which can play an important role in the precise hourly planning of units. As it was said, the basic and social policy here requires the maximum efficiency of renewable energy sources. In other words, as long as we can use renewable energy sources, we should not use fossil energy sources. As it was said, the battery will provide the role of compensating the necessary power for industrial and agricultural units. Fig. 5 shows the amount of production power by each of the units for twenty-four hour planning. As can be seen, the necessity of optimal planning in this network is well known. What is clear from this figure is the necessity of using renewable energy sources in the middle hours of the day to reduce the production power by fossil sources. In addition, the use of batteries has made the surplus production capacity of renewable resources usable at other times. This issue not only reduces costs, but also improves social welfare from a social point of view. Considering the proximity of renewable energy sources to consumers, the psychological effects of these sources on consumers will be well known. The main power grid will always play an important role in providing energy stability as an alternative. In the end, it is clear that optimization tools can play their role as a fundamental factor in creating a balance between producers and industrial consumers.

Conclusion

In this research, appropriate tools were investigated to create a balance between producers and industrial consumers. As stated, the three basic and key actors of this game are renewable energy sources and energy storage and optimization and programming methods. In this regard, the advantages and disadvantages of each of the following tools were well examined. In addition, it was tried to explain the interdependent map of these tools and the mutual influence between them. In the end, using the genetic algorithm, the proposed model and the effect of each of these tools on the three big industrial, agricultural and residential consumers were investigated. The results clearly show that these tools can have many economic, technical and social effects on human life. Undoubtedly, the use of renewable energy sources improves social welfare and reduces emissions. The use of batteries can lead to sustainable energy and improve efficiency in parallel with renewable energy sources. Finally, proper optimization methods will play an irreplaceable role in reducing costs and, as a result, improving social well-being.

Declaration of Competing Interest

There is no conflict of interest associate with this submission. We also confirm that this research is neither under review nor published in somewhere else.

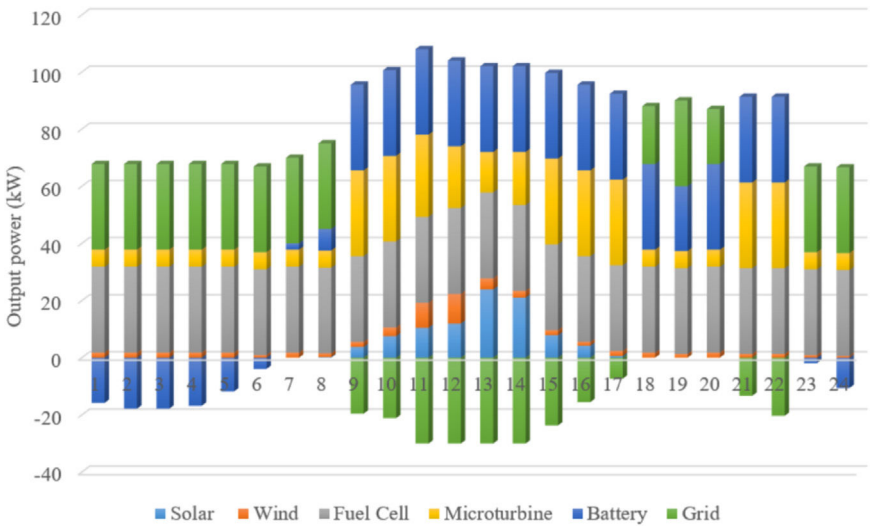


Fig. 5. Hourly scheduling of the units using optimization tool, renewable sources and battery as key players.

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