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Embedded Selforganizing Systems

Electricity Consumptions Study of Power Deficit System: Assisting forecasts for Demand Side Management

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***Abstract*— In a world where energy requirements are increasing faster than our ability to generate it, it is important to manage the consumption of electricity efficiently. This article looks at how demand-side management (DSM) strategies can be adapted for use in systems with power deficits to improve the reliability and sustainability of the electricity supply. We also study different DSM methods such as load shifting, peak shaving, and demand response; assessing their effectiveness in alleviating shortages of electric power. Our results show that through DSM, immediate deficits can be relieved while at the same time creating opportunities for enhancing energy efficiency and integrating renewable sources of power. The introduction of demand-side management into the energy system can significantly enhance electricity efficiency, reduce greenhouse gas emissions, and maintain ecological balance. This offers a promising solution to the current challenges and a brighter future for Mongolia's energy sector. A proposed framework for adapting DSMs provides practical guidance for decision-makers in government and utility companies interested in implementing strong interventions at the demand side which would ultimately lead to more resilient and sustainable electricity systems.**

***Keywords*— electricity, export, import, source, electricity distribution licensee**

I. Introduction

Demand Side Management (DSM) is a strategy that electric utilities use to control electricity demand. It does this by encouraging customers to change when they use electricity, especially during peak hours, or to use less electricity overall. A DSM program usually offers financial rewards, like discounts on energy-efficient equipment or lower rates for using electricity at less busy times, to meet the different needs of customers.

In order to lower peak loads, control time of use (TOU) levels of power demand, evaluate user profiles for electricity loads, lower carbon emissions, and provide consumers with a choice of preferred energy source, the electrical industry originally developed the DSM in 1970 [2, 3], [24, 25].

Several nations, including the UK [20] , China [21], North America [22], and Turkey [23], have adopted the Energy Management System (EMS). This system is a crucial part of demand-side management, as it is the most effective way to save energy costs while keeping the energy system stable. However, there are still some challenges that prevent EMS from being fully implemented in underdeveloped nations. These challenges might be related to [2]:

- Adopting an EMS comes at a significant expense, and the long-term rate of return on investment is low.
- Time-varying electricity tariffs are ideal. However, switching from an older model to a newer one is challenging for electrical companies and merchants.
- Not all stakeholders benefit equally from the transformation. Population knowledge has a significant impact on implementation speed.
- Upgrading the network infrastructure could be very expensive for the system, and bidirectional power flow is still in the research stage, which could delay the idea of EMS.

Nowadays, the global demand for electrical energy has increased. Hence, it is crucial to utilize new alternative energy resources to reduce the adverse environmental impacts caused by conventional energy sources such as fossil fuels.

Thus, the integration of various sorts of distributed energy resources (DERs), such as renewable energy sources (RESs), is expanded into modern power systems (MPSs). By looking specifically at global energy consumption in 2022, it represents about 160.8 petawatt hour (PWh) in which fossil fuels such as oil, coal, and gas participate, with large percentages of this amount are 32.95%, 27.90%, and 24.52%, respectively, as depicted in fig. 1. while other clean energy resources record the remaining percentage. Various industrial countries have implemented urgent procedures to decline this global energy consumption, which varies yearly, as shown in Fig. 2. The energy consumption in 2021 recorded an incremental variation of 5.46%. However, it declined to around 1.11% in 2022. Energy consumption decreased to small amounts (lower energy production) due to economic crises and the coronavirus pandemic in 2009 and 2020, respectively [4].

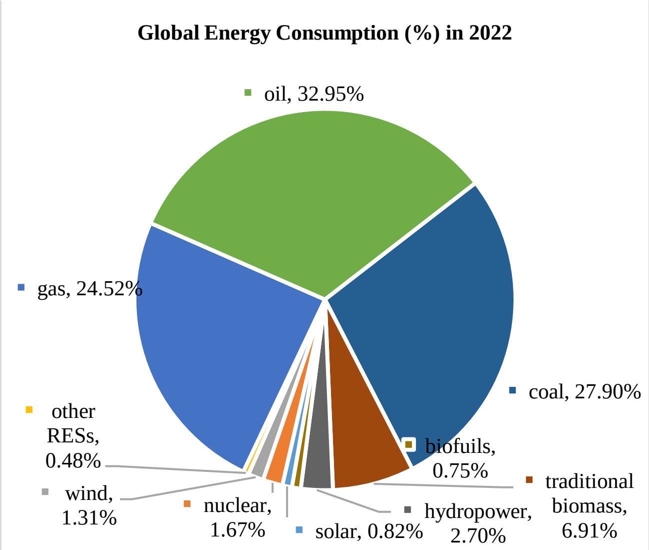

Fig. 1. Global Energy Consumption in 2022

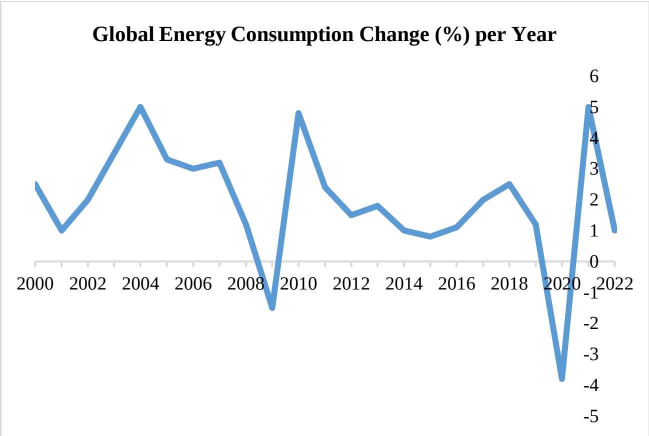

Fig. 2. Global Energy Consumption per Year

Given Mongolia's current power shortage and reliance on imports, adopting this strategy is not only a logical step but also a proven one, based on international experience, instilling confidence in its potential effectiveness.

Mongolia's energy system consists of five parts: the Central Electric System (CES), the Western Region Energy System, the Altai-Uliastein Energy System, the Eastern Region Energy System, and the Southern Region Power Supply (Fig.3). The Central Electric System (CES) is the most loaded and extensive in terms of installed capacity and electricity consumption compared to other regions [6-8].

CES works in parallel with the Southern Region, Altai-Uliastein energy system. The system is connected to 8 combined heat and power plants, one battery storage power plant, seven solar power plants, three wind power plants, and the 220 kV Darkhan and Selendum substations of the Buriad power system of Russia; works in parallel operation with overhead power lines. As of 2023, 79.8% of the total electricity consumption in Mongolia is consumed by the CES, while the consumption of the Southern Region is 13.1%, the Eastern region 3.1% in the Western region 2.6% in the, and 1.3% in the Altai-Uliastai.

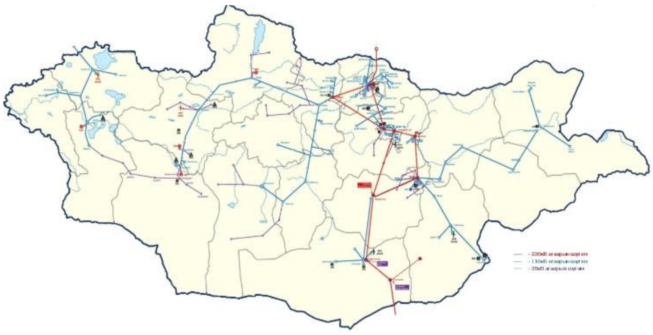

Fig. 3. Energy systems of Mongolia

Let us now turn our attention to the outcomes of demand-side management and the successful international practices that have been implemented. These case studies serve as a testament to the effectiveness of DSM and provide reassurance about its potential in the Mongolian energy sector.

Case study 1- Maharashtra State Electricity Distribution Company Ltd (MSEDCL) Replacement of 5000 Old CeilingFans by 5-Star Rated Ceiling Fans approximately 80 watts energy, which is 30% less than the conventional ceiling fans of substation end and expected 125 kW demand savings Rs.575/ year/fan (payback < 2 years) Some more DSM initiatives by MSEDCL are as listed in which a village (Goathan) can avoid load shedding in the evening by reducing the load voluntarily to 20% of the existing load public due to load shedding is in the evening hours. Single-phase transformers are being fixed in the village so that essential lighting can be available in the households. The pump system operates during off-peak hours to help reduce peak and energy demand.

Outcomes: Energy-efficient fans result in 25 watts saving and 11 hrs/day use, resulting in 0.4 M kWh reductions. About 5,548 villages and five towns have been covered, leading to 1,260MW of load relief through APY. These villages are now free from planned load shedding of 14 hours. They now receive 21 hours of uninterrupted power supply. MSEDCL has contributed to the reduction of the Maharashtra system demand by 1260 MW in the system demand over 14700 MW, thereby improving the power situation in the state.

Case study 2- BESCOM efficient Light: Program (BELP)

For the first time in India, BESCOM started DSM activity on 05.11.2007. International Institute for Energy Conservation (IIEC), Washington, was a consultant for BESCOM. It was based on replacing incandescent bulbs with compact fluorescent lights (CFLs) consumers, which facilitated the removal of price and quality barriers. Experiment in India with potential replication of incandescent lamps with CFLs.Rs. 1.5 million.

- Demand savings: 13.5 MW
- Energy savings: 24.3 Million Units
- Cost savings: Rs. 0.7 million

Outcomes: It was estimated that about 1.81 Lakhs additional CFLs were sold during the scheme implementation. About a 100% increase in sales of CFLs was observed compared to the previous year, which resulted in a reduction in residential demand to the extent of 10.46MWs.This pilot project encouraged the country to formulate the Bachat Lamp

Yojana, Which forced manufacturers to give customers a one-year warranty. This scheme leads to regulation stipulating a minimum power factor of 0.85 for CFLs.

II. Research Section

For Ulaanbaatar, Mongolia, peak load is a critical issue affecting energy production and other issues, including air quality. Mongolia's electric energy consumption increased by an average of 344 million kWh or 6.0% in the last ten years. Fig 4. shows Mongolia's electricity consumption growth from 2013 to 2023.

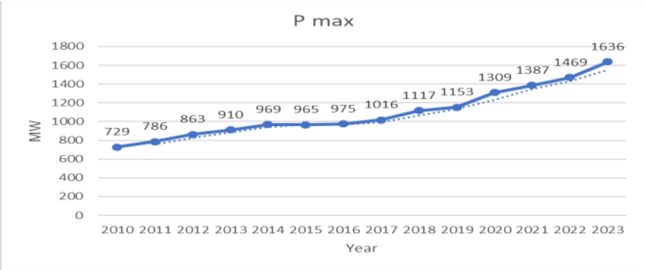

Fig. 4. Electricity production and distribution in the central region

The daily electricity consumption during winter is high, with a high load in the central electric system of about 25.0-31.7 million kWh, and the difference between high and low winter loads is about 280-400MW. Fig 5. shows Mongolia's peak capacity growth from 2010 to 2023.

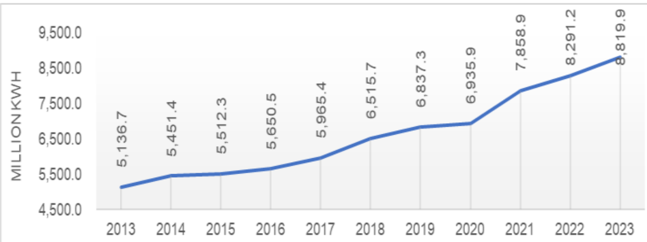

Fig. 5. System peak load MW

Compared to the summer mode, thermal power plants have a relatively more significant opportunity to reduce their electricity load during low-load hours at night during winter. Fig 6. shows the contribution and limitations of resources to winter peak loads.

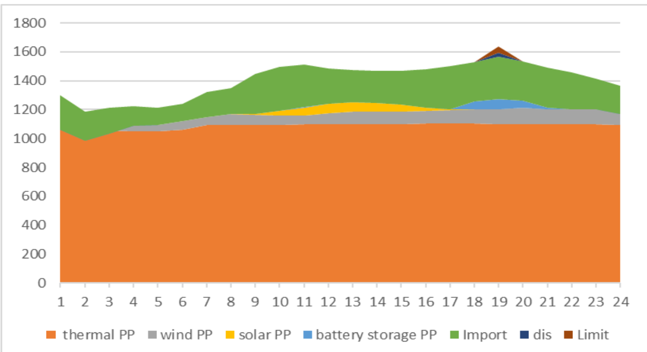

Fig. 6. Load graph of winter peak days in the central region

Electricity is imported during morning and evening peak hours, and a small amount of electricity is exported during the night off-peak hours.

Forecast of electricity consumption

The National Energy Agency's forecast of the electric load is based on the load growth of the past years and the data of the newly connected large users. Let us look at electricity consumption and its growth in the last five years.

- Data for the last five years
- Year-on-year growth and decline
- Monthly increases and decreases
- Intraday fluctuations
- Hourly increments and decrements
- Impact of outside air temperature on system load
- Consumption calculation using the regression method

Tables I and II display the growth in electricity consumption by energy and capacity from 2018 to 2023.

TABLE I. Electricity consumption growth in the central region's integrated network over the past five years.

	2018	2019	2020	2021	2022	2023
Consumption, million kWh	5709	6014	6109	6992	7380	7891
Growth, million kWh	490.7	304.6	95.0	883.3	388.1	511.1
Growth rate	9.4%	5.3%	1.6%	14.5%	5.6%	6.9%

TABLE II. Electricity load of the integrated network of the central region in the last five years

	2018	2019	2020	2021	2022	2023
Peak load MW	1115	1153	1309	1387	1469	1636
Difference in peak load MW	99	38	156	78	87	167.1
Growth rate	9.7%	3.4%	13.5%	6.0%	6.3%	11.4%

The December consumption was calculated in the table, including how to accommodate the winter peak load, how to optimally plan the consumption by month, how to use the regression method to plan the consumption based on the load of previous years, and how to calculate the relationship between the months and days.

Table III compares the capacity of the months with heavy winter loads with the load of previous years and determines the capacity of the next winter months by extracting the increase in correlation between months and days.

TABLE III. The correlation between year, month, and day, demonstrates the fluctuations in forecasted consumption for December.

Day	Sep month	Oct month	Nov month	Dee month	Jan month	Feb month	Mar month
1	0.854	0.896	0.890	0.943	0.892	0.943	1.000
2	0.865	0.923	0.910	0.949	0.962	0.949	0.999
3	0.866	0.922	0.908	0.951	0.987	0.951	0.991
4	0.880	0.923	0.922	0.953	0.999	0.953	0.995
5	0.886	0.926	0.919	0.960	0.992	0.960	0.986
6	0.880	0.927	0.920	0.970	0.993	0.970	0.980
7	0.882	0.935	0.924	0.966	0.984	0.966	0.957
8	0.878	0.955	0.919	0.967	0.986	0.967	0.913
9	0.877	0.943	0.923	0.965	0.982	0.965	0.958
10	0.884	0.948	0.923	0.970	0.983	0.970	0.967
11	0.890	0.944	0.926	0.965	0.981	0.965	0.970
12	0.900	0.951	0.919	0.970	0.981	0.970	0.964
13	0.905	0.950	0.922	0.980	0.986	0.980	0.966
14	0.917	0.969	0.934	0.993	0.994	0.993	0.961
15	0.899	0.961	0.933	0.994	0.989	0.994	0.978
16	0.928	0.971	0.937	1.000	0.997	1.000	0.958

Day	Sep month	Oct month	Nov month	Dee month	Jan month	Feb month	Mar month
17	0.933	0.977	0.951	0.991	0.990	0.991	0.956
18	0.941	0.970	0.956	0.982	0.986	0.982	0.946
19	0.955	0.968	0.958	0.979	0.982	0.979	0.965
20	0.967	0.987	0.958	0.980	0.978	0.980	0.961
21	0.956	0.990	0.963	0.971	0.980	0.971	0.960
22	0.959	0.984	0.973	0.972	0.992	0.972	0.958
23	0.974	0.979	0.965	0.967	0.996	0.967	0.953
24	0.958	0.981	0.964	0.965	1.000	0.965	0.946
25	0.957	0.997	0.963	0.976	0.998	0.976	0.936
26	0.952	1.000	0.957	0.971	0.986	0.971	0.934
27	0.978	0.992	0.974	0.978	0.991	0.978	0.926
28	0.996	0.982	0.992	0.985	0.992	0.985	0.930
29	0.999	0.986	1.000	0.964	0.980	0.964	0.919
30	1.000	0.982	0.995	0.964	0.970		0.915
31		0.989		0.977	0.976		0.908
Day	**Sep month**	**Oct month**	**Nov month**	**Dee month**	**Jan month**	**Feb month**	**Mar month**
1	960	1188	1331	1477	1367	1358	1291
2	972	1223	1362	1487	1474	1367	1289
3	974	1222	1358	1490	1513	1370	1280
4	989	1223	1379	1494	1531	1373	1285
5	996	1227	1375	1504	1521	1382	1274
6	989	1228	1376	1519	1522	1396	1265
7	992	1238	1382	1514	1508	1391	1235
8	986	1265	1375	1515	1512	1392	1179
9	985	1249	1381	1513	1506	1390	1237
10	993	1256	1381	1520	1508	1396	1249
11	1000	1250	1386	1513	1503	1390	1252
12	1011	1260	1375	1519	1504	1396	1245
13	1018	1258	1379	1536	1512	1412	1247
14	1031	1284	1397	1556	1523	1430	1241
15	1010	1274	1395	1557	1516	1431	1262
16	1043	1286	1401	1567	1529	1440	1237
17	1049	1294	1423	1554	1517	1428	1234
18	1058	1285	1430	1539	1512	1414	1221
19	1074	1282	1434	1534	1506	1409	1246
20	1087	1308	1433	1536	1500	1411	1241
21	1075	1312	1441	1521	1502	1398	1240
22	1078	1303	1456	1523	1520	1400	1237
23	1094	1297	1443	1515	1526	1393	1230
24	1077	1300	1442	1513	1533	1390	1221
25	1076	1321	1441	1529	1530	1405	1208
26	1070	1325	1432	1521	1512	1398	1205
27	1099	1314	1457	1532	1520	1408	1195
28	1119	1301	1485	1543	1521	1418	1201
29	1123	1306	1496	1511	1503	1389	1186
30	1124	1302	1488	1510	1487		1181
31		1310		1531	1497		1172

Due to the COVID-19 epidemic in 2020, 2021, and 2022, the government decided to subsidize energy prices to the state, resulting in a sharp increase in demand. As a result, when studying and calculating the average growth over the years, these years should not be included. The average growth for years with moderate growth was 5.0%; for high-growth years, it was 7.0%; and for low-growth years, it was 3.0%.

Table IV. shows the forecast for electricity consumption until 2030, with medium and high growth and significant new applications.

- Low growth – 5.0%
- Average growth – 5.0%
- high growth – 7.0%

TABLE IV. PROJECTED ELECTRICITY CONSUMPTION CAPACITY OF THE INTEGRATED NETWORK IN THE CENTRAL REGION UP TO 2030 (MILLION KWH)

Year	Low growth	Average growth	High growth
2023	7,891.5	7,891.5	7,891.5
2024	8,128.3	8,286.1	8,443.9
2025	8,372.1	8,700.4	9,035.0
2026	8,623.3	9,135.4	9,667.5
2027	8,882.0	9,592.2	10,344.2
2028	9,148.4	10,071.8	11,068.3
2029	9,422.9	10,575.4	11,843.0
2030	9,705.6	11,104.2	12,672.1

Table V shows the peak load capacity of the central region's integrated network until 2030, calculated for low, medium, and high growth. It includes new sources of increase, data from recent years, weather forecasts, and annual, seasonal, and monthly growth.

- Low growth – 3.0%
- Average growth – 4.6-5.5%
- high growth – 8-11.5%

TABLE V. FORECAST OF WINTER PEAK LOAD CAPACITY FOR THE INTEGRATED CENTRAL REGION NETWORK UNTIL 2030 (MW)

Year	Low growth	Average growth	High growth
2023	1636	1636	1636
2024	1685	1711	1824
2025	1736	1805	2007
2026	1788	1904	2207
2027	1841	2009	2428
2028	1897	2120	2671
2029	1953	2236	2884
2030	2012	2359	3115

Demand-side management aims to enable users to monitor their energy consumption considering peak energy demand. Continuous monitoring and management of energy consumption aim to enhance system reliability while reducing energy costs [11-18] .

Possibilities of introducing demand side management in Mongolia:

- Phased implementation of innovative measures and automatic management systems;
- Monitor household electricity usage from 5 PM to 10 PM using time-dependent pricing;
- Create databases for users' electricity usage information;
- Create a gratuity system - It is establishing a system to provide consumption plans, peak load power orders, and actual consumption orders in the energy supply contract;
- Classification of consumer economic activities by sector and sub-category, modifying the sales registration information system, and enabling analysis opportunities.

Demand-Side Management Program Types, Stakeholders, Institutional Scope, and Opportunities:

Procedure implementer:

- Development of demand-side management procedures
- Dispatch energy companies

Energy companies:

- Development of demand-side management programs
- Commission of demand-side management program

Private sector:

- Provide demand-side management services

End users:

- Utilize the demand-side management programs/products
- Give feedback and create demand.

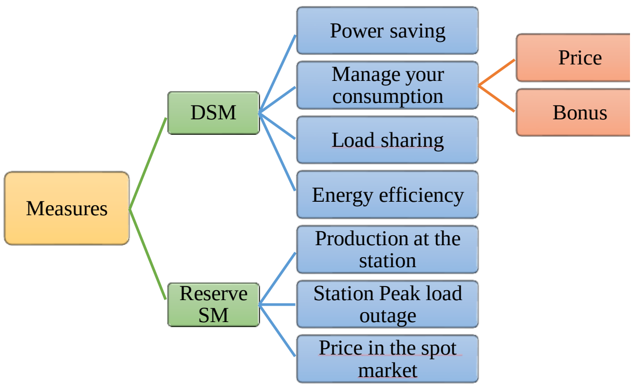

Fig. 7. Details of DSM

When electricity consumption increases daily, and there is a power shortage, the correct consumption calculation can prevent many risks. Table VI. provides a detailed overview of electricity consumption until 2030, encompassing growth patterns from previous years, significant power consumers, and newly established enterprises.

TABLE VI. CONSUMPTION FORECAST UNTIL 2030

Month/Pmax	*Oct month*	*Nov month*	*Dee month*	*Jan month*	*Feb month*	*Forecast*
2010	651	690	729	711	684	104.9%
2011	684	748	786	734	706	107.8%
2012	755	824	863	808	791	109.8%
2013	808	855	910	875	842	105.4%
2014	832	916	969	907	892	106.5%
2015	856	954	965	931	901	99.6%
2016	896	959	975	973	948	101.0%
2017	933	1005	1016	994	938	104.2%
2018	973	1059	1117	1081	1040	109.9%
2019	1050	1139	1153	1112	1070	103.2%
2020	1082	1123	1309	1148	1130	113.5%
2021	1175	1321	1387	1281	1253	106.0%
2022	1225	1441	1469	1361	1337	105.9%
2023	1296	1506	**1636**	1474	1384	111.4%
2024	1305	1690	**1763**	1562	1559	107.7%
2025	1570	1798	**1912**	1710	1685	108.5%
2026	1497	1850	**2073**	1830	1775	108.4%
2027	1790	1965	**2245**	2018	1898	108.3%
2028	1820	2190	**2428**	2105	1925	108.2%

III. IMPLEMENTATION OF DEMAND-SIDE MANAGEMENT

The text explains how load-shaping strategies can affect load curve patterns. For instance, the green curve depicts the original load curve before applying the load shaping (LS) strategy [1], [9, 10]. However, after implementing LS, the load increases during off-peak periods and decreases during peak periods, represented by the red curve.

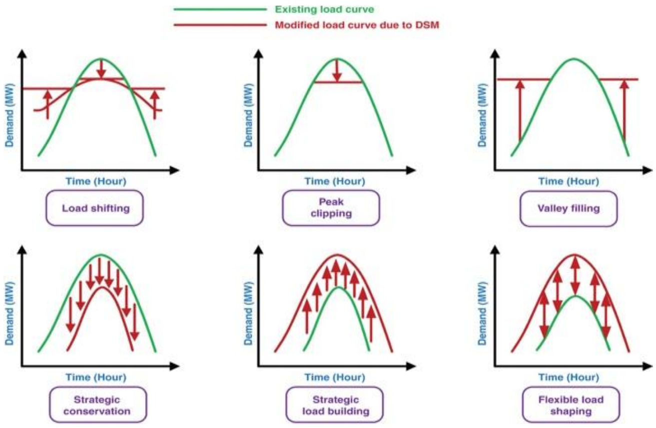

Fig. 8. Load-shaping strategies of DSM [1]

- Load shifting- LS can shift the load from peak to off-peak periods, effectively managing valley filling and peak clipping. The modeling of DSM with a day-ahead LS strategy is emphasized.
- Peak clipping- Peak clipping is a method in which the load is reduced during peak periods.
- Valley filling- The Valley filling strategy involves increasing the load during off-peak hours.
- Strategic conservation- Strategic conservation reduces the total amount of energy used annually
- The load building changes the load pattern, leading to an overall increase in annual energy consumption.
- Flexible load shaping- The utility can modify the load pattern to meet its reliability requirements by adjusting the load curve based on the generation-load mismatch

DRPs are utilized to encourage customers to modify their load profiles [1], [2], [23-24]. They are divided into time-based demand-response programs (TBDRPs) and incentive-based demand-response programs (IBDRPs). TBDRPs include flat pricing (FP), time-of-use pricing (TOU), real-time pricing (RTP), critical peak pricing (CPP), and RGDP. Additionally, IBDRPs comprise DLC, I/C service, CMPs, EDRPs, A/S programs, and DB programs.

Incentive-based DRPs:

- ✓ Direct load control
- ✓ Emergency Demand Response Programs
- ✓ Capacity Market Programs
- ✓ Interruptible/curtaible services
- ✓ Ancillary Services Programs
- ✓ Demand Bidding/Buyback Programs

Time-based DRPs:

- ✓ Flat pricing
- ✓ ToU pricing
- ✓ Real-time pricing

- ✓ Critical peak pricing
- ✓ Renewable generation-based dynamic pricing

Load Shifting with Battery Energy Storage Systems:

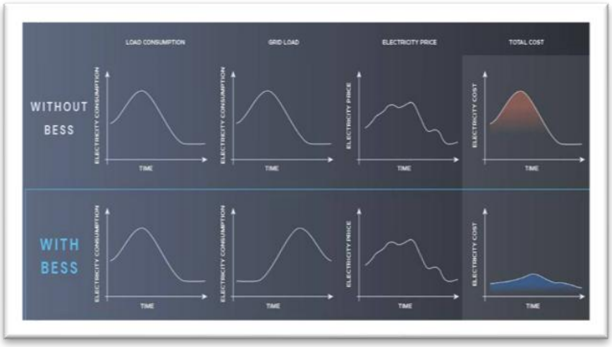

Fig. 9. Load Shifting with Battery Energy Storage Systems

It is not always profitable to shift loads between peak loads to benefit from market prices. However, with battery energy storage systems, load shifting is always profitable. Battery energy storage systems allow end users to separate energy consumption from utility bills. Industrial and commercial customers with battery energy storage systems can benefit from shifting load without changing business operations. For example, a factory can charge its batteries at night during off-peak hours and use the energy stored during the day when market prices are at their highest, reducing electricity bills. By using battery energy, a customer can reduce power shortages during peak hours.

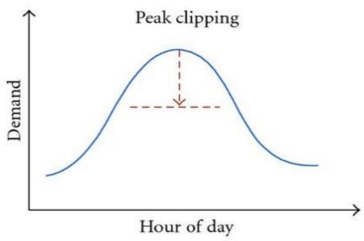

Fig. 10. Peak clipping

When electricity demand is high, there is a sharp increase in the load curve. To manage this, peak clipping is used to reduce the highest loads on the system. Typically, this is achieved through a method known as direct load control (DLC), which helps align electricity demand with supply. Utilities implement this strategy to manage peak loads effectively, which can delay the need for new power plant construction and result in cost savings. Peak clipping is implemented through interruptible or curtailable demand response programs aimed at industrial and commercial customers.

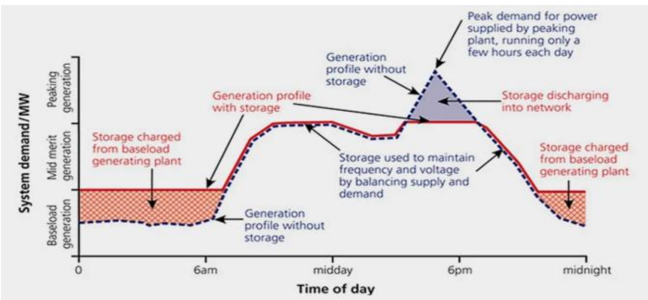

Fig. 11. Peak shaving and valley filling energy storage project

Valley filling involves increasing electricity usage during off-peak hours to flatten the load curve. A common example of valley filling is charging electric vehicles (EVs) during the night when electricity demand is lower.

IV. Conclusion

Due to Mongolia's lack of resources during the peak season, it is impossible to stop the increase in consumption, so it is necessary to limit consumers' electricity consumption and ensure the system's stability.

Mongolia plans to consume electricity daily and in the medium and long term, balancing the load of the source and the user. As a country that imports electricity from the Russian Federation at peak times, it is essential to understand the value of energy to users, accurately estimate the load of consumers, study large-capacity equipment, and regulate energy prices.

In this research, Mongolia's short-, medium-, and long-term consumption is planned until 2030; the load of new sources that will be put into use and the increasing consumption load of consumers are planned in hours, days, months, and years. Regression methods and multi-year data have been studied to determine how inter-year growth and decline correlate. In China's study of 2018, based on the forecasts, there can be a reduction of around 100 million kW in the installed power capacity by 2020, which is more than the installed capacity of 5 mega projects if DSM projects are implemented effectively.

Even if the source is put into operation, international experience shows that the user load grows with it. Therefore, in terms of policy, policy-making organizations such as the Ministry of Energy, the Energy Regulatory Commission, and the National Dispatch Center should come up with plans to implement consumer management in Mongolia in stages, change tariffs, reduce the burden on consumers affecting the system during peak periods, and create incentives is effective. Mongolia is fully capable of implementing user-side management. Implementing consumer management is an effective way to reduce greenhouse gas emissions, which affect the environment.

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