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RESEARCH ARTICLE

A Review on Demand Side Management in an Indian Village: Scope and Challenges

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Abstract

Objectives: This study reviews the scopes and challenges of Integrated Resource Planning in power distribution system of an Indian tribal village Dedali-B. This study supports to the management of the demand of power, especially in rural place. **Method:** The optimal scheduling of the studied Demand Side Management has been observed using Binary Particle Swarm Optimization taking the management of the demand in mind. The BPSO is capable to handle binary variable hand has the property of parallelism, scalability and adaptability and converge to good solutions quickly when Demand Side Management is concerned. **Findings:** The Integrated resource planning in power distribution system has been conducted for minimizing of energy consumption in this paper through simulation. It is found that in village Dedali-B, through scheduling of the loads using BPSO, the bill of energy consumption reduces to ~15% when commercial loads are considered. Also, it was observed through the comparative study of residential and agricultural loads before and after demand response that the peak load is reduced to 9.12% while cost is reduced 6.57%. The peak to average ratio is reduced 21.95%. **Novelty:** A specific ideology suitable for implementation of integrated resource planning through optimization and DMS supports the demand management and reduces the costs. It has been examined through a test case of tribal village Dedali-B of Dhar district in India.

Keywords: Demandside management; demand and supply; integrated resource planning; distributed generation; distributed energy resources

1 Introduction

India has a large population in the world. The population requires proportional energy resource facilities for their development and welfare. The most of the population lives in villages. Indian villages have tremendous and sustainable demand-side resources for energy management in power distribution systems. Therefore, India has a scope of Demand-Side Management (DSM) in power distribution system with their challenges. There is a need to review present situations in supply-demand of power distribution system, feasibility of demand-side management concept with respect to availability of Demand-Side Resources (DSRs), tools, techniques and suitable methodology for a specific location and condition (country and world scenario).

Many previous research articles may available on applications of demand-side management, but not reviewed on the specific area. Article[1] provides basics of DSM, but not mention the methods basically applicable in the in this tribal area of India. However,[2] describes the analytical aspects of supply-demand in power distribution system as per human behavior and energy market context. This article has not mentioned scope of energy resources available and its coordination with objectives and methods of demand-side management concept and its challenges for this specific area. Similarly,[3] mentions free cost energy conservation through behavior through training in Indian perspective, but does not mention the area based scopes, resource available and its coordination with different resources. Incorporation of different resources has been analyzed using DSM concepts in[4]. This article provides information that can be used in an Integrated Resource Planning (IRP) or Hybrid Energy System (HES)[5] in a rural area through optimization techniques[6]. DSM is a concept that has different objectives. These objectives cannot be achieved without Demand Response (DR) that is mentioned in[7]. But in rural areas that have lot of demand-side resources[8] and conditions that may adopt different DR for convenience the consumers.

Nevertheless, in the above literature regarding India have not emphasized on scopes and discussion on integrated resources planning, implementation and evaluation considering the challenges related to variations of consumer behaviors due to natural and human activities under different conditions in a specific area village Dedali-B of Dhar district in India by DSM with demand and supply study (understanding).

This paper identifies the problems and scopes of power distribution system in a tribal rural area village Dedali-B of Dhar district in India. It discusses the scope of energy harnessing in the area with respect to India and world scenarios. It explains demand-side management objects and methods to address the identified problems. It also describes integrated resource planning specifically for a tribal village Dedali-B in Madhya Pradesh state of India and their challenges.

The rest of this paper is arranged as follows. Section-II provides methodology as scopes, supply and demand concept for utilizing that information in demand-side management in specific condition. Section-III explains results and discussions as integrated resource planning and its impacts of natural and human activities on energy requirements and different challenges in a specific area. Section-IV presents conclusions and future scopes.

2 Methodology

2.1 Scope

The world scenario in shown in Table 1 shows the position of India in energy consumption. According to this, India has 7th position and many scopes to harness energy resources available in demand-side as major population of India lives in villages.

As in Figure 1, India is situated on the globe north of the equator between 8°4´and 37°6´north latitude and 68°7´and 97°25´east latitude. It has good solar radiations. It has average temperature. Madhya Pradesh is a heart of India. Dhar district is west of Madhya Pradesh which is hilly area and below the Malwa Plateau. This area has great scope of renewable energy as solar, wind, biomass and hydro-micro power plant (in rainy season).

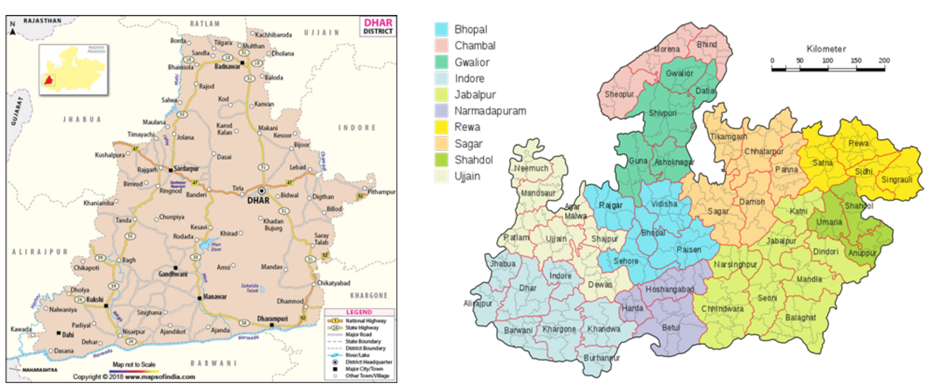

Fig 1. Geo-political representation of Dhar district

As per the studies[2], the data of the Tables 1 and 2 show the different levels of status in a large difference of electricity in different regions of the world and India. And the human activities depend on education, available resources, technologies, income, living style and development in a particular area. So, the authors first need to identification and classification of different area of India as Regions, States, Divisions, Districts, Tehsils, Blocks, Panchayats, and Villages for understanding electric demand and supply according to the activities in that area. Then understand the loads and markets issues and correlate these with previous implemented DSM in the same environmental and human conditions with resources for proper allocation as per demand[9,10]. Define load shape objectives for obtaining with DSM and formulate program concept and portfolios with proper measurements. Now, analyze the cost-benefit with demand and supply concept for the objective and design a detailed program. Do the analysis for the improvement, check-out for the desired goal. Implementation should be with proper follow-up management and evaluation with time.

Table 1. World data of energy consumption[2]

Country (Area)	Electricity Generation resources (All in TW)								Electricity consumption (MWh/yr)							Per Capita
	Fossil fuel			Renewable					NC	Resi	Com	Agr	Ind	Tras	Oth	
	Coal	Oil	Gas	Hyd	Wind	PV	Geo	Bio+		(All in %)						
World	41%	5.50%	21%	16%	1.10%	0.64%	0.30%	1.30%	13	27.4	23.4	2.5	41	1.6	3.43	313
USA	2133	58	911	282	56	2.48	17	73	838	363	35	-	24	0.2	4.59	1402
UK	127	6.1	177	9.3	7.1	0.02	-	11	622	27.4	25.6	0.88	44.7	1.33	-	622
Germany	291	9.2	88	27	41	4.4	0.02	29	148	26.5	22.6	1.66	46.1	3.14	-	861
Japan	288	139	283	83	2.6	2.3	2.8	22	258	29.8	36.4	0.09	31.5	1.95	5.05	774
China	2733	23	31	585	13	0.2	-	2.4	68	15.5	5.4	3.12	67.8	1.05	7.19	442
India	569	34	82	114	14	0.2	-	2	15	20.7	8	17.92	46.4	1.93	5.05	883.6
Nigiria	-	3.1	12	5.7	-	-	-	-	-	55.3	24.7	-	20	0.07	-	12
Egypt	-	26	90	15	0.9	-	-	-	-	39.2	15.4	1.13	33.4	-	7.84	147
Aus	198	2.8	39	12	3.9	0.2	-	2.2	-	34.5	28.6	1.14	33.2	2.47	-	1114
Iran	0.4	36	173	5	0.2	-	-	-	-	32.3	19	12.92	33.2	1.15	2.5	305
Brazil	13	18	29	370	0.6	-	-	20	14	23.2	23.7	4.49	48.1	0.39	-	268

India has 1.21 billion populations which shares 17% world population. India is second largest country after China in the world population. In India, rural and urban population distribution is 68.84 % and 31.16 % respectively with electric energy consumption and requirement growth rate of 10% and 8%[3]. So, India has good potential in natural as well as human resources in different areas activities. Hence, different region/area has different data in electric power sector as in Table 2 as follows.

The costal and sea areas have good wind energy resources. And also, the whole land area of India is very suitable for solar electricity resource. The climate of the India is monsoon. So, most of the land is used for agriculture. As from the Table 2, the electricity used is 7.3% in agriculture (IR), 9.3% in industrial (ID), 10.5% in commercial (CM), 11.9% in domestic (DM), 9.5% in utility (UT) and 8.9% in other sector. The Table also shows the electricity consumption in different regions (area) as north region (NR), south region (SR), west region (WR), east region (ER), northeast region (NER) and islands of India with indication of the different activities and developments. India's economy very much depends on agriculture and growing towards industrial and technology with strong economic growth driven by real GDP growth of 8.7%in the last 5 years. Hence, India has a great potential of human resources and markets for demand side management in electric power sector which is very much suitable and important.

Table 2. Indian data of energy consumption[2]

Area	Electricity Generation resources (All in TW)					Electricity consumption (MWh/yr)							Per Capita
	Fossil fuel			Renewable		NC	Resi	Com	Agr	Ind	Tras	Oth	
	Coal	Oil	Gas	Hyd	RES		(All in %)						
NR	35283	13	5231	5455	670	1620	10.8	11.5	11.2	10.4	10.5	10.2	833
WR	54069	17.48	9738	7447	9925	1840	8.4	10.7	10.6	4.6	9.1	8.3	1201
SR	26582	939	4962	11398	13127	1620	8.9	9.9	11	7.3	8.6	9.4	938
ER	34583	17.2	190	4113	417	0	11.4	17.7	5.5	8.1	9.2	6.1	521.2
NER	60	142.74	1208	1242	252	0	13.9	20.1	12.2	8.1	8.8	7.1	0

World is divided in seven continents with different natural and human activities with different allocation of resources among population. There is more than seven billion populations. Population is increasing and the conventional source availability is decreasing. The adverse effect on environment is increasing due to climate changes caused by external forces as human activities.

In the world's different parts climate is different due to their location, terrain, altitude, nearby water bodies and their currents. Therefore, there is variation in temperature, weather, humidity, atmospheric pressure, and other meteorological variation in a region over a time (long or short).

Because of these variations in the natural activities, there is variation in resources availability and human activities in a particular region (area) of the world. The utilization and allocation of the available scarce natural resources depend on the human activities as development, technologies, civilization, industrialization and needs of requirements.

According to the variations in the activities, the electricity requirement, generation, management and impact on environment also different for different regions, countries and areas as in Table 2.

Tables show data in percentage for electricity generations and consumption of different countries of different areas with different resources of generation and consumption. The electric power generation is now shifting from fossil fuels as coal, oil, gas to towards the renewable energy resources as hydro (Hyd), wind, photovoltaic (PV), Tidal (TD), geothermal (Geo) and biomass (Bio). The nuclear (NC) energy is also an important resource for electricity generation. There are four major end use sectors: commercial (Com), industrial (Ind), residential [Heating (HT), Cooling (CL), Lighting (LT)], Transportation (Tran). The electric power sector (PS) also consumes energy.

Thus, in the same and/or different conditions each and every country has its own technology, policy and capability to use available resources. For example, Japan with many ups and downs of accidental, environmental and economic issues have emerged strongly in photovoltaic energy use due to its suitable policy and innovative technology according to available resources.

An analysis of energy problems and issues requires a comprehensive presentation of basic supply and demand data for all resources of the market. This gives building blocks for madding suitable planning, implementation, evaluation and overall management to obtain a desired goal concerning with the problems and issues for a specific market and area conditions; and then this provides ways for its implementation increasingly in a large scale (area). For example, in electric market, demand side management started from California of the USA in 1970s with energy issues and at present, it is increasingly spreading over the world[11].

2.2 Demand and Supply

The demand and supply of electric power, like any other commodity, are fundamental to understanding how the electrical grid functions and how energy markets operate. The demand and supply curves of electric power represent the relationship between the quantity of electric power demanded and supplied at various price levels. These curves help illustrate how changes in price and quantity impact the electricity market. Figure 2 shows a typical demand and supply curve.

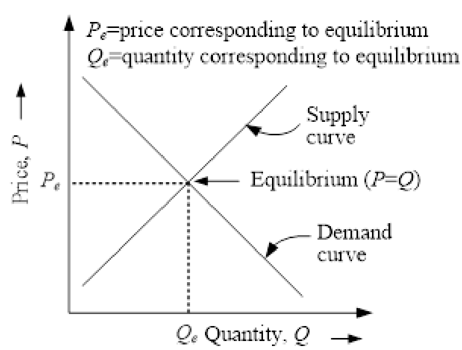

Fig 2. Typical demand and supply characteristics

The demand curve typically slopes downward from left to right, indicating that as the price of electricity decreases, the quantity demanded increases, and vice versa. This is known as the law of demand while the supply curve typically slopes upward from left to right, indicating that as the price of electricity increases, the quantity supplied by producers also increases. This adheres to the law of supply. Several factors influence the position and shape of the demand curve for electric power, like price elasticity time of day and economic activity. Similarly, various factors influence the position and shape of the supply curve for electric power are generation sources, regulatory environment and technological advances. The demand curve for electric power shows how consumers' willingness to purchase electricity changes with price, while the supply curve illustrates how producers' willingness to supply electricity changes with price. The interaction of these curves determines market prices and quantities in the electricity market, with fluctuations based on various factors influencing demand and supply.

A market is the locus of exchange where simply buyers and sellers coming together for transactions as shown in Figure 3. Through the circular flow, one can better understand the interdependency of a market sector.

The circular flow diagram includes as inside the pyramid is integrated resource planning where the parties obtain and sell the energy; the factor which is shown in the dashed arrows circle are where the utilities parties obtain and supply the energy resources under the regulated policy to gain the suitable profits and the investment sector in base indicates that the same buying and selling of electricity with investment by private, public private or public sectors. The circular flow diagram shows that each of the sectors relies on the others for resources and supplies interdependency.

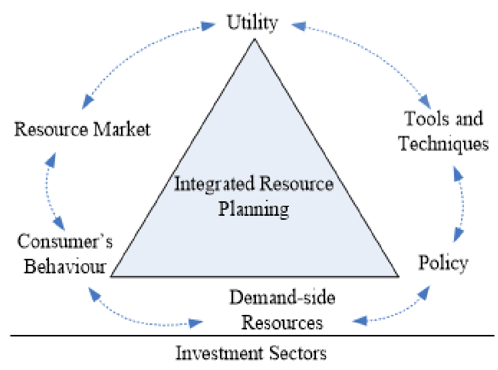

Fig 3. Circular flow diagram for Integrated resources interdependency

As in Figure 4**(a)** Law of Demand states that as price increases consumers will purchase less and vice versa. It has negative slope as shown. The slope depends upon utility (use, pleasure, jollies) from the consumption, changes in utility (marginal utility), income effect, substitutive effect and diminishing marginal utility [31]. Diminishing marginal utility is the fact that at some point further consumption adds smaller and smaller increment to the total utility received from the consumption. Economic Profit (EP), Demand (D), and Marginal Revenue (MR) can be analyzed through Figure 4 **(b)**.

The law of supply states that more the supply, the higher the price. Supply schedule at the quantities supplies at each and every price. The supply curve is a positive relation between price and quantity of a supply curve as in Figure 4**(b)**. A market supply and demand are simply an aggregate of all individual supply and demand curves [12].

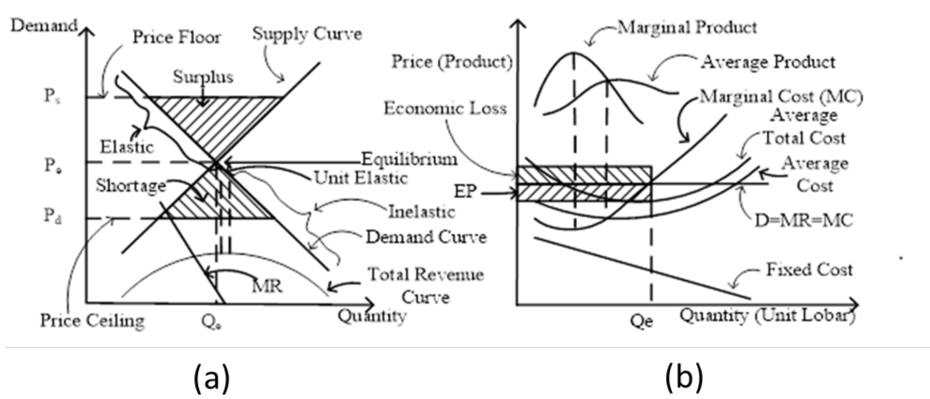

Fig 4. (a) Demand and Supply curves, (b) Costs with Demand curves [2]

Elastic demand means that the quantities demanded respond more than proportionality to changes in prices. The elastic demand coefficient is more than one. The inelasticity of demand means that the quantities demanded respond less than proportionality to changes in prices. The inelasticity of demand coefficient is less than one. Under unit elasticity of demand, the quantities demanded respond proportionality to changes in prices. The unit elasticity of demand coefficient is exactly one[13].

The price elasticity depends on substitutability, proportion of income, luxuries versus necessities and time which one suitable for demand side management in electric power sector. The price elasticity of supply is determined by the following time frames. The more time, a producer has to adjust output the more elasticity supply. This depends on market period, short run, long run. Cross elasticity of demand measures the responsiveness of the quantity demanded of one producer to changes in the price of another producer. The income elasticity of demand measures the responsiveness of the quantity demanded of to changes in customer price.

The understanding on concept of demand and supply, equilibrium of market under demand and supply, elasticity of demand and supply, inelasticity of demand, cross elasticity, income elasticity and their constraints provide important information for planning, implementation, monitoring and evaluation in demand-side management in for desired changes in electric power distribution systems[14,15].

2.3 Concept of Demand- Side Management

Demand side management (DSM) in electric power sector started in 1970 from the USA in California states in response of rising oil price (cost). It has also been issues to improve its image in public hostility for reducing cost issues and environmental issues. In the early 1980s, it started in the context of integrated resources planning for cost reduction and meeting energy demand in the United States. Demand response and integrated resource planning increased the importance of DSM for utilities through changes for incentives set by regulators[16,17]. By the regulators calculated the allowed rate of return, many utilities in the United States became profitable and less dependent upon the numbers of units sold. Demand-side programs had been implemented many states of the USA, Canada, and Australia, numbers of European, African, South American and Asian Countries.

At regional or multi-national level, in 1999, the International Energy Agency (IEA) proposed that all countries harmonize energy efficiency policies to reduce standby power to 1 Watt or less per device in all products. Further the IEA proposed that all countries adopt the same definition and test procedure, but that each country uses measure and policies to its own circumstances. 480 TWh, standby energy each year has been estimated worldwide. It can be reduced to 60 to 80 percent.

Demand-side management in electrical sector includes demand response, integrated resource planning, distributed energy resources in demand and supply[18]. It has six objectives as shown in Figure 5. Peak clipping, valley filling and load shifting are traditional; while strategic conservation, strategic load growth and flexible load shape are new objectives.

In Indian tribal village Dedali-B, the consumer's behaviors for energy consumption are different than that of the urban energy consumers. They have lower education and skills, but have a large scope for development and demand-side resources availability. Hence, all objectives of DSM can be achieved through the demand response methods as shown in Figure 6.

These all DSM objectives can be fulfilled by demand response methods. But, these methods depend on various factors of consumers' behavior as discussed in demand and supply Sub-section. The demand response convinces the energy consumers providing some incentives. These methods broadly can be classified into two categories as shown. The electric energy efficiency has also come under the demand response concept. The demand-side management can be implemented on the electrical energy market of demand and supply. The demand and supply in electric sector depend on various factors of natural and human activities in an area as discussed in demand and supply Sub-section.

2.4 Demand-Side Resources in a Tribal Village Dedali-B of Dhar

Dedali-B village is located in Gandhwani -Tehsil of Dhar district in Madhya Pradesh, India. Dhar district of India is a 'Scheduled Area'. It is reserved for tribal community. Most of the tribes are Bhil, Bhilala, Barela and Patelia. These are almost all farmers. These communities are socially, financially and educationally very backward and in developing stage. These live in remote areas.

The area of Dhar district is almost dried. 'Kharif' and 'Rabi' both the crops are produced. But depend on the rainy season 'Monsoon' and river water (rainy and winter seasons). This area includes 'Vindhyachal Range' of forest which is western boundary of 'Malwa' plateau. The Dhar district touches Indore in East. Indore is the cleanest city of India and known as 'Mini-Bombay'. It has 'Education Hub' of Madhaya Pradesh. It has the nearest industrial area 'Pithampur' which in Dhar district. The west of Dhar is 'Alirajpur' and 'Jhabua' district of India. These districts are also Scheduled Area for tribes. These districts touch the boundary of Gujarat state of India. The velocity of wind in this area is supported by Arabian Sea. In totality, physical structure of the district area includes two parts: Part-I: 'Malwa' plateau and Part-I: 'Nimar' region. The study is conducted in Part-II, which is west of Part-I. The Part-II is hilly due to Vindhyachal Range and at lower level from Part-I (Malwa). Tropic of

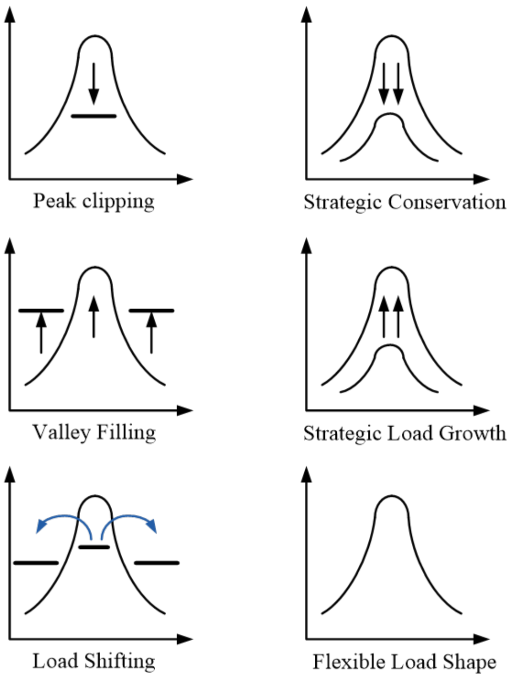

Fig 5. Demand-side management objectives

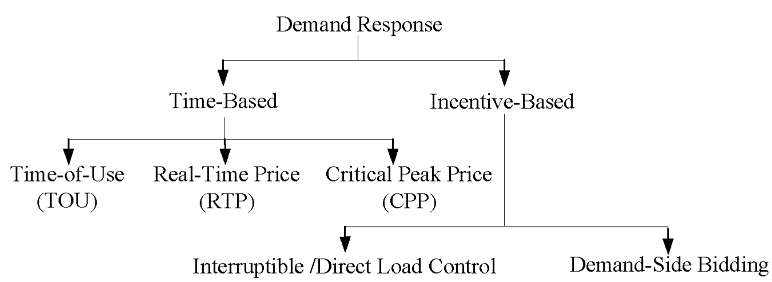

Fig 6. Demand response methods

Cancer passes near to the Dhar district.

Thus, physical and social conditions, both have scope of energy harness in the village Dedali-B area of Dhar district in India. Production of wastage from farms and cattle can be used for energy harness through small or micro biomass or biogas power plants. Solar has also a great scope for renewable energy generation using PV systems. Similarly, wind and micro-hydro power plants have also great scopes for energy harness. The area has also utility infrastructure through which generated power can be supplied to 'Pithampur' industrial area and Indore city for income of the Village Dedali-B. The study area has lot of demand-side resources availability for electric power generation and distribution. The need of the area is to make a suitable and sustainable integrated resource planning for local energy networking using smart technologies[17–19].

3 Results and Discussion

Natural and human activities play an important role in allocation the natural and human resources for generation of electricity according to requirement and their impacts on environment. The impact of the IRP on the DMS has been examined and discussed in this section.

3.1 Integrated Energy Resource Planning

An integrated energy source planning is a design of an electrical power system integrating all the available resources with tools and techniques. The above discussed concept of DSM are suitable to implement in a tribal village Dedali-B of Dhar district in India by designing a Local Area Energy Network or a Hybrid Energy System as shown in Figure 7. Because, the tribal society in the village are in developing stage and every modern development needs concentration on specific use of electrical energy.

This integrated resource planning includes renewable energy resources as well as conventional sources in the combination of two or more forms of energy sources as solar, wind, biomass, micro-hydro power, energy storage systems; and end-use technologies to deliver uninterrupted power supply. This system is reliable in this area, because, as discussed, this location has lot of scope for solar, wind, and biomass energy harness. It also has micro-hydro power plant in rainy and winter seasons. The village Dedali-B have the utility power distribution. At the time of irrigation, the utility is overloaded.

The integrated resource planning will help to reduce the overload of the utility[20]. The village Dedali-B consumer's energy will be reduced by the system. The bill of the energy consumption will be minimized. Hence, the villager's income will be increased. The utilization of local energy sources will increase and dependency on utility will decrease. Therefore, the reliability of energy supply will also be better. This system is sustainable for environment due to use of more renewable energy sources[21,22]. The most of the villagers use cattle dung and tree branches or biomass waste of farms for energy in cooking and other works. This increases environment bad. The designed system will also decrease the impacts.

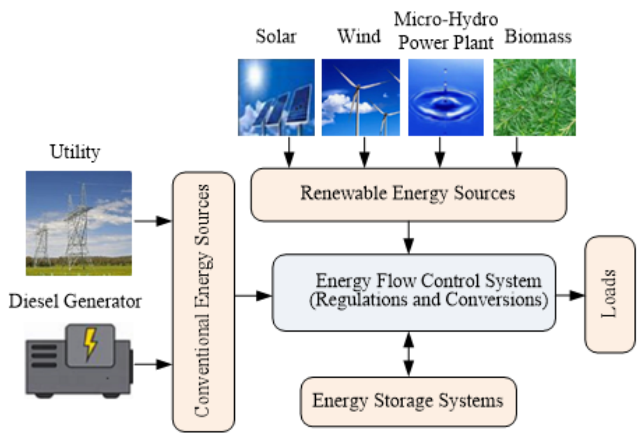

Fig 7. Schematic of an integrated energy source planning

The energy consumption of the village Dedali-B of Dhar district annually is about 10,200 kWh (2018)[10]. During power outages, diesel generators are being used for backup. The energy consumption is mainly due to irrigation pumps of 3 HP, 5 HP and 7 HP. A research in the village Dedali-B has been conducted for minimizing of energy consumption around 15 % and 21 to 25 % bill through scheduling of the loads using Binary Particle Swarm Optimization (BPSO). The results obtained as follows in Tables 3 and 4.

Table 3 provides data for comparative study with scheduling of commercial loads before and after demand response. The reduction of peak load is 23.25 %; while cost is 7.2 % and Peak-to-Average Ratio (PAR) is reduced 23.24 %.

Table 3. Result comparison for commercial loads

Parameters	Without DSM	With DSM obtained by BPSO	% Reduction
Peal load (kW)	1366	1046.5	23.25
Cost	2302.9	2136.43	7.22
PAR ratio	1.85	1.42	23.24

Similarly, Table 4 provides data for comparative study of residential and agricultural loads before and after demand response. In this case, peak load is reduced 9.12 %; while cost is reduced 6.57 %. The peak to average ratio is reduced 21.95 %.

From the study, it can be clearly seen that there are lot of scopes for integrated resource planning and scheduling of demand-side resources for energy consumption and cost minimization through smart great technology and optimization techniques[23].

Table 4. Result comparison for home and agriculture loads

Parameters	Without DSM	With DSM obtained by BPSO	% Reduction
Peal load (kW)	756	687	9.12
Cost	1035	967	6.57
PAR ratio	1.23	0.96	21.95

3.2 Challenges

Demand side management in India introduced by literature Nadel et al.[24] in 1990s with the effect of DSM in the USA and worldwide. The DSM came in planning and implementation in India in 8th five-year plan (1992-1997) to save 5000 MW and 6 million tones petroleum funding with Rs. 1000 crores. During the 11th five-year plan, Bureau of Electricity Efficiency (BEE) and Ministry of Power (MOP) has introduced a number of schemes for promotion of energy efficiency in India[25].

After, almost fulfillment of 'one nation one grid' dream in 11th five-year plan (FYP), 12th FYP is conducting government's low carbon growth strategy to ensure the sustainable development of the power sector with DSM schemes. In this way, enactment of the Electricity Act 2003, National Electricity Policy (NEP) 2005, Integrated Poly 2008and Energy Conservation Act 2011 with State Electricity Regulation Commission (SERC), State Design Agency (SDA), and National Action Plan on Climate Change (NAPCC).

The State Designated Agency (SDA) is a nodal agency in many states in India that advises the SERC for suitable enabling the policy of DSM with State Energy Contribution Conservation Fund (SECF). The states like Gujarat, Tamil Nadu, Maharashtra, Himachal Pradesh, Rajasthan, Andhra Pradesh, Mizoram, Chhattisgarh, Haryana, and Karnataka have been adopted regulation under the EA 2003 and NEP 2005.

Thus, worldwide and countrywide lot of programs are being conducted. However, the challenges for the success are continued and will be continued. Similarly, in the village Dedali-B of Dhar district, there are lot of challenges related policies, social, cultural, educational, and financial. Hence, due to lack of awareness, there is difficult to convince the villagers and implement the concepts. There are also need of a smart networking infrastructure to conduct the integrated resource planning.

4 Conclusion

This investigation provides the basic understanding of demand-side management concept to implement an integrated energy resource planning with supply-demand and various activities (behaviors) in a tribal village Dedali-B of Dhar district in India. In the village Dedali-B, there are lot of scopes for energy harness, minimization of energy consumption and costs. It was observed that through scheduling of the loads using Binary Particle Swarm Optimization (BPSO), the bill of commercial loads reduces to ~15 %. Also, it was found through the comparative study of residential and agricultural loads before and after demand response that the peak load is reduced to 9.12 % while cost is reduced 6.57 %. The peak to average ratio is reduced 21.95 %. This will help in the development of the village. But, more or less, there are many situations, issues, activities and conditions which are different in various parts of India. This understanding is very important for India to construct the infrastructures in electric power sector as it is developing countries where proper electrification has a need. In the future, the DMS with the proposed optimization can be performed for the peak load management, electric vehicle charging management, behavioral change and public awareness, data analytics and prepare the energy pricing models.

References

1) Premkumar R, Shanmugasundaram R, Thilak KR, Balaji ANVSS. A Review on Demand Side Management: Definition, Scope, Challenges and Benefits. In: 2022 8th International Conference on Smart Structures and Systems (ICSSS), 21-22 April 2022, Chennai, India. IEEE. 2022;p. 1–4. Available from: https://ieeexplore.ieee.org/document/9782161.
2) Sisodiya S, Tanwar SS, Prajapat GP. An analytical review of unable demand side management in Indian power market context. *Journal of Emerging Technology and Innovative Research*. 2017;4(5):614–636. Available from: https://www.jetir.org/papers/JETIR1705112.pdf.
3) Ali SS, Tyagi R. Free of Cost Energy Conservation through Behavioural Training: an Indian Perspective. *Journal of The Institution of Engineers (India): Series B*. 2022;103(5):1563–1575. Available from: https://doi.org/10.1007/s40031-022-00768-w.
4) Sisodiya S, Kumbhar GB, Alam MN. A home energy management incorporating energy storage systems with utility under demand response using PSO. In: 2018 IEEMA Engineer Infinite Conference (eTechNxT), 13-14 March 2018, New Delhi, India. IEEE. 2018. Available from: https://doi.org/10.1109/ETECHNXT.2018.8385345.
5) Kumar S, Sharma S, Sood YR, Upadhyay S, Kumar V. A Review on different Parametric Aspects and Sizing Methodologies of Hybrid Renewable Energy System. *Journal of The Institution of Engineers (India): Series B*. 2022;103(4):1345–1354. Available from: https://doi.org/10.1007/s40031-022-00738-2.
6) Panda S, Mohanty S, Rout PK, Sahu BK, Bajaj M, Zawbaa HM, et al. Residential Demand Side Management model, optimization and future perspective: A review. *Energy Reports*. 2022;8:3727–3766. Available from: https://doi.org/10.1016/j.egyr.2022.02.300.

7) Behera MS, Jain SK. A Review on Different Techniques of Demand Response Management and its Future Scopes. In: 2021 International Conference on Control, Automation, Power and Signal Processing (CAPS), 10-12 December 2021, Jabalpur, India. IEEE. 2022;p. 1–8. Available from: https://ieeexplore.ieee.org/document/9730732.
8) Sisodiya S, Kumbhar GB. Demand-Side Resources for Electric Energy Management. In: 2018 4th International Conference on Electrical Energy Systems (ICEES), 07-09 February 2018, Chennai, India. IEEE. 2018. Available from: https://ieeexplore.ieee.org/document/8442335.
9) Adhikari TR, Sisodiya SL. Three phase load balancing in an Indian village using blink application. *International Research Journal of Engineering and Technology (IRJET)*. 2021;08(11):1495–1499. Available from: https://www.irjet.net/archives/V8/i11/IRJET-V8I11244.pdf.
10) Bhongade S, Dawar RS, Sisodiya SL. Demand-Side Management in an Indian Village. *Journal of The Institution of Engineers (India): Series B*. 2022;103(1):63–71. Available from: https://doi.org/10.1007/s40031-021-00639-w.
11) Nuñez I, Cano EE, Cruz E, Rovetto C. Designing a Comprehensive and Flexible Architecture to Improve Energy Efficiency and Decision-Making in Managing Energy Consumption and Production in Panama. *Applied Sciences*. 2023;13(9):1–20. Available from: https://doi.org/10.3390/app13095707.
12) Kou X, Li F, Dong J, Olama M, Starke M, Chen Y, et al. A Comprehensive Scheduling Framework Using SP-ADMM for Residential Demand Response With Weather and Consumer Uncertainties. *IEEE Transactions on Power Systems*. 2021;36(4):3004–3016. Available from: https://ieeexplore.ieee.org/document/9302627.
13) Chen S, Jiao L, Liu F, Wang L. EdgeDR: An Online Mechanism Design for Demand Response in Edge Clouds. *IEEE Transactions on Parallel and Distributed Systems*. 2022;33:343–358. Available from: https://ieeexplore.ieee.org/document/9448461.
14) Mohanty S, Panda S, Parida SM, Rout PK, Sahu BK, Bajaj M, et al. Demand side management of electric vehicles in smart grids: A survey on strategies, challenges, modeling, and optimization. *Energy Reports*. 2022;8:12466–12490. Available from: https://doi.org/10.1016/j.egyr.2022.09.023.
15) Dey B, Márquez FPG, Bhattacharya A. Demand side management as a mandatory inclusion for economic operation of rural and residential microgrid systems. *Sustainable Energy Technologies and Assessments*. 2022;54:102903. Available from: https://doi.org/10.1016/j.seta.2022.102903.
16) Parvin K, Hannan MA, Mun LH, Lipu MSH, Abdolrasol MGM, Ker PJ, et al. The future energy internet for utility energy service and demand-side management in smart grid: Current practices, challenges and future directions. *Sustainable Energy Technologies and Assessments*. 2022;53(Part C):102648. Available from: https://doi.org/10.1016/j.seta.2022.102648.
17) Kanakadhurga D, Prabaharan N. Demand side management in microgrid: A critical review of key issues and recent trends. *Renewable and Sustainable Energy Reviews*. 2022;156:111915. Available from: https://doi.org/10.1016/j.rser.2021.111915.
18) Abba ZYI, Balta-Ozkan N, Hart P. A holistic risk management framework for renewable energy investments. *Renewable and Sustainable Energy Reviews*. 2022;160:1–18. Available from: https://doi.org/10.1016/j.rser.2022.112305.
19) Patil P, Kazemzadeh K, Bansal P. Integration of charging behavior into infrastructure planning and management of electric vehicles: A systematic review and framework. *Sustainable Cities and Society*. 2023;88:104265. Available from: https://doi.org/10.1016/j.scs.2022.104265.
20) Rodrigues SD, Garcia VJ. Transactive energy in microgrid communities: A systematic review. *Renewable and Sustainable Energy Reviews*. 2023;171:112999. Available from: https://doi.org/10.1016/j.rser.2022.112999.
21) Rezaeimozafar M, Monaghan RFD, Barrett E, Duffy M. A review of behind-the-meter energy storage systems in smart grids. *Renewable and Sustainable Energy Reviews*. 2022;164:1–21. Available from: https://doi.org/10.1016/j.rser.2022.112573.
22) Ahammed MT, Khan I. Ensuring power quality and demand-side management through IoT-based smart meters in a developing country. *Energy*. 2022;250:123747. Available from: https://doi.org/10.1016/j.energy.2022.123747.
23) Facchini A. Distributed energy resources: Planning for the future. *Nature Energy*. 2017;2(8):17129. Available from: https://doi.org/10.1038/nenergy.2017.129.
24) Barik AK, Das DC. Integrated resource planning in sustainable energy-based distributed microgrids. *Sustainable Energy Technologies and Assessments*. 2021;48:101622. Available from: https://doi.org/10.1016/j.seta.2021.101622.
25) Graditi G, Somma MD. Chapter 13 - Conclusions and key findings of optimal operation and planning of distributed energy resources in the context of local integrated energy systems. *Distributed Energy Resources in Local Integrated Energy Systems*. 2021;p. 419–425. Available from: https://doi.org/10.1016/B978-0-12-823899-8.00013-3.