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LOAD SCHEDULING AND SOLAR BASED ENERGY COST OPTIMIZATION FOR CONSUMERS IN DEVELOPING COUNTRIES

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ABSTRACT

To solve the energy crisis in India, it is very important to develop smart algorithms to gain a mush quicker solution to the power cut problems. India, it is filled with a lot of basic essential issues that first needs to be solved such as continuous access for drinking water to all, food for all and most importantly electricity for all. This paper talks about how combining solar energy, load shifting and partial outage can benefit the consumers to tackle the power cut problems. Knowing the power cut scenario in the local areas, the step one of the algorithm calculates, the loads that can be shifted during the power cuts, the second algorithm calculates how much benefit can be obtained from the solar power that is being generated in the consumer premises, and finally how much of the back-up i.e. the diesel consumption of the diesel generator can be reduced.

KEYWORDS: Load Shifting, Power Shortage, DSM, Power Management.

I. INTRODUCTION

By the end of calendar year 2015, despite poor hydro electricity generation, India has become power surplus country with huge power generation capacity idling for want of electricity demand. The calendar year 2016 started with steep fall in the international price of energy commodities such as coal, diesel oil, naphtha, bunker fuel and LNG which are used in electricity generation in India. Earlier many of the power stations which are using fuels other than coal are unable to operate due to high cost of LNG and petro products. This situation has changed due to glut in petroleum products globally. The prices are falling to such an extent that these fuels have become cheaper to give competition for pit head coal based power generators. Many of the stranded gas and liquid fuel based power stations would be competing with indigenous coal based power stations in an electricity market where demand growth is not encouraging. All the segments of the electricity sector such as fuel suppliers, fuel transporters (railways, harbours, pipelines, etc.), Electricity generators, electricity transmission companies and distribution companies would be facing severe competition to cut down the prices and improve their operating efficiency in a final consumer dictated market. If Discoms, keep on charging exorbitant tariffs to bulk consumers, they would be opting for solar / wind power plants or take over an existing power plant to meet their captive consumption.

II. METHODOLOGY

The MATLAB methodology to model the demand side management optimization and scheduling are described in this section. The MATLAB code is structured in such a manner that it fetches all the input data from various excel files, these excel files can be edited for demand, for the individual load power characteristics, for the load start time, the load run time, for forecasted outage start time & outage duration etc., Once these inputs are ready we can go to the MATLAB GUI to run the code. Once the code is run for a forecasted outage it results in a new load schedule for the following day depending on the outage. Due to the unreliable grid, we have assumed an error in the outage scenario of maximum of 1 hour on either sides of the forecasted outage. Thus to simulate this unreliable grid we do a real time fuzzy logic based DSM on the loads by creating an error in the outage either in the outage start time or outage end time or even both. Thus depending on the actual outage the fuzzy logic rule base is referred for a further correction in the load schedule to reach to the best optimal cost. The baseline costs assumed for the grid is 5c/KWhr (residential) and the baseline diesel costs assumed in the simulation are 20 c/KWhr. As the power characteristics of the loads are not constant we have divided the day into multiple of a 5 minutes chunk, so 24 hours is considered as 288 chunks, by doing this we can be very accurate in calculating the effective cost, for a better and simple understanding we have assumed all the heavy loads considered in the paper i.e. 3 Geysers, 1 washing machine, 1 dishwasher & a dryer to have flat power characteristics curves. As seen below the table 1 shows the establishments in an area. All calculations are done with respect to house 1 at hour 9, having a requirement of 5.8 KWh.

TABLE 1: Table containing the load profile's of all the users in an area

Sl.No	BUILDINGS	Sanctioned Load (kW)	Time t (hr)																							
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	House 1	6	0.89	0.83	1	0.84	0.9	0.59	1.7	3.3	5.8	5.8	1	1.8	0.74	0.7	0.8	0.5	0.52	2.49	2	2.3	2	2.3	0.7	0.88
2	House 2	20	2.848	2.66	3.2	2.69	2.88	1.89	5.3	10	18	19	3	5.8	2.37	2.3	2.6	1.7	1.66	7.97	6.4	7.36	6.4	7.36	2.24	2.82
3	Hotel 1	30	10	10.2	8	7.5	10	8.4	8.4	10	11	11	11	12	13	15	15	16	8.3	9	9	15	16.2	18.2	18.3	13
4	House 3	10	1.068	1	1.2	1.01	1.08	0.71	2	3.9	6.9	6.9	1.1	2.2	0.89	0.9	1	0.6	0.62	2.99	2.4	2.76	2.4	2.76	0.84	1.06
5	Hospital 1	20	11.4	9.39	0.24	6.74	3.24	15.9	6.2	11	3.3	12	5.3	13	13.8	15	9	1.7	4.58	18.3	3.05	16.5	10.8	19.9	1.56	8.85
6	Mall 2	30	0.4	0.45	0.4	0.4	0.3	0.3	0	0	1	20	19	21	21	21	18	17	17	26	27	27	27.5	15	13	6
7	House 4	10	1.36	1.26	1.52	1.28	1.37	0.90	2.54	5.00	8.76	8.82	1.45	2.77	1.13	1.10	1.22	0.81	0.79	3.79	3.05	3.50	3.05	3.50	1.07	1.34
8	School 1	30	3	3	3	3	3	1	2	5	10	11	15	20	20	22	20	25	20	7	4	4	3	3	3	3
9	Shop 3	14	0.18	0.20	0.18	0.18	0.14	0.14	0.00	0.00	0.45	9.09	8.64	9.55	9.55	9.55	8.18	7.73	7.73	11.82	12.27	12.27	12.50	6.82	5.91	2.73
10	Hospital 2	30	17.1	14.1	0.36	10.1	4.86	23.9	9.3	16	5	18	7.9	20	20.7	23	14	2.5	6.87	27.5	4.575	24.8	16.2	29.9	2.34	13.3
		200	48	43	19	34	28	54	38	64	71	121	73	107	103	110	89	74	68	117	74	115	100	109	49	53

Load Shifting Technique:

The cost minimization equation is as follows: Input parameters
LPASSIVE(t) - Passive Load at time t
LSHIFT,i(t) - Shiftable Load i at time t
Total Load ∑(L(t)) = ∑LPASSIVE(t) + ∑LSHIFT,i(t) for i=1,n tG Grid available time for a day
tB Diesel usage time in a day
CG(tG) Cost per unit with grid
CB(tB) Diesel cost per unit
Total cost per unit at time t C(t) = CG(tG) + CB(tB)
Total Cost CTOTAL = ∑C(t)L(t) for t = 0,24
COPT = Min (CTOTAL)
Algorithm: - Finding optimal load schedule is done by following the below mentioned flowchart in Figure 2.

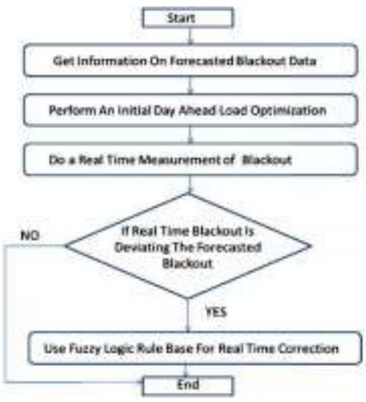

Figure 2: Basic algorithm flow chart

$L1_{NrsT}$ - Normal Start Time Of Load (1)
$L1_{NST}$ - Earliest Start Time Of Load (1)
$L1_{LST}$ - Latest Start Time Of Load (1)
$L1_{RT}$ - Run Time Of Load (1)
$L1_{NrET}$ - Normal End Time Of Load (1)
$L1_{NrET} = L1_{NrsT} + L1_{RT}$

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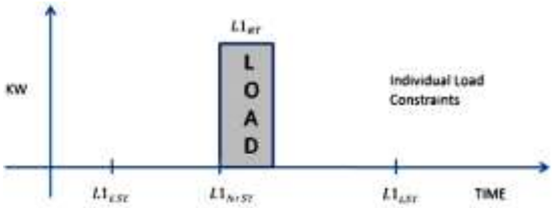

Figure 3. Load schedule constraint

Figure 3 speaks about how every shiftable load is normally scheduled & also what are its constraints i.e. the load cannot be shifted randomly during the day but has an earliest start limit & also a latest start limit. Hence any shifting of these loads has to be done between this time frame.

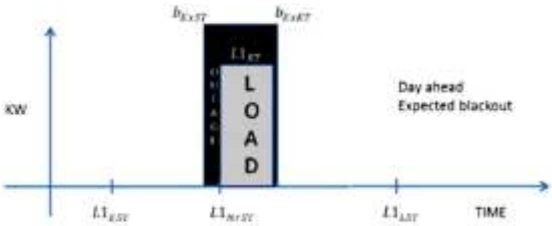

Figure 4. Expected outage for the following day

b_{ExST} - Expected Outage Start Time
b_{ExST} - Expected Outage End Time

In **Figure 4** we can clearly observe that the outage is expected to affect the load, thus this load has to be shifted, Thus the load is scheduled to a new start time either before the outage or after the outage, this completely depends on the load constraints & also the runtime of the load, if the gap is available on both sides of outage, the algorithm chooses to shift the load before the outage as it is safer to execute the load beforehand, rather to risk the execution of the load with the unreliable grid supply. This is seen in **Figure 5**.

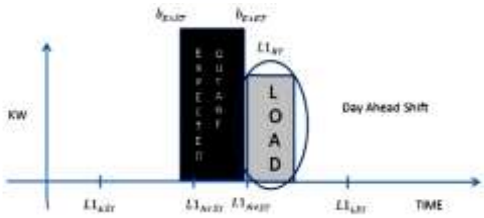

Figure 5 Day ahead Load Shift Schedule

$L1_{NeST}$ - New Expected Load Start Time
$L1_{NeET}$ - New Expected Load End Time
$L1_{NeET} = L1_{NeST} + L1_{RT}$

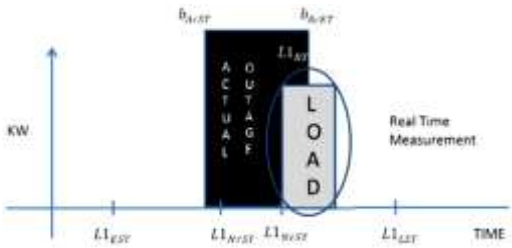

Figure 6. Actual Outage

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b_{AcST} - Actual Outage Start Time
b_{AcET} - Actual Outage End Time

In **Figure 6** we can observe that the actual outage is overlapping the new scheduled start time of the load, this data is obtained from the real time supply sensors. Now the real time Fuzzy Logic Rule base for this kind of a scenario where a second shift of the load is required comes into action. The rule mentioned below comes into action & the load is shifted at the b_{AcET} as shown in figure 7.

If $b_{AcST} \leq L1_{NeST}$ & $L1_{NeST} \leq b_{AcET} \leq L1_{NeET}$ =>2nd Shift

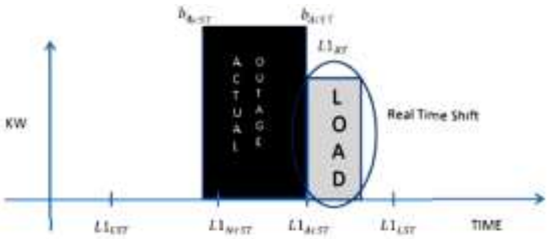

Figure 7. Actual Load Schedule.

$L1_{AcST}$ - Actual Load Start Time
Thus the $L1_{AcST} = b_{AcET}$

All the shiftable loads undergo this exercise to get the best possible optimal solution to attain the least cost, by finally reaching COPT = Min (CTOTAL)

Solar based optimization: In this algorithm during a full power condition i.e. during normal condition, the power is being supplied at 100%, during the power cut based on this information the other supplies available the 1st algorithm will implement the load shifting technique as explained above and reduce the requirement of load during the shortage of power supply. Further to this the 2nd algorithm is initiated to further optimize the back up and solar supply available and to deliver to the customer a highly optimized cost of uninterrupted power supply.

In this case the solar capacity installed on the roof top of the consumer is assumed to be equal to the sanctioned load. During normal power supply availability the generated solar power is pumped to the grid and during the scheduled outage the solar power is supplied to the consumer load, hence optimizing the back-up diesel cost.

III. RESULTS

Now in table 2 we can observe that for a, house 1 observed from table 1, the savings after applying the 1st algorithm is around 90% and in the 2nd case after applying the 1st and 2nd algorithm the total earnings is around Rs 28/- day.

TABLE 2: Shows the savings in cost by using Solar

Supply Required (Watts)	Shiftable Load (Watts)	Solar supply (Watts)
5745	3500	3027
5745	3500	3027
5745	3500	3027
5745	3500	3027
Cost (Rs) Using Diesel Generator	Cost (Rs) After Load Shifting	Earnings (Rs) after Load Shifting and Solar
114.9	11.225/90.23	28.94
114.9	13.4/88.33	27.55
114.9	40.7/64.57	10.15
114.9	19.55/82.98	23.63

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IV. CONCLUSION

Every establishment is different and has its own unique constraints, but the energy supplies are limited. Hence it is very important to choose the right combination of energy sources at right time of the day to achieve the best possible cost optimization possible. The case studies highlight the importance of the algorithms developed, where the customers can benefit greatly from the implementation of the previously mentioned solutions. The study also showed that the actual savings potential depends on the timing of power outage, duration and the specific load characteristics. As diesel prices increase, the economic benefits of these solutions are also increasing correspondingly. Developing countries should consider specific approaches to mitigate power outages and provide relief to customers. Although challenges exist in the implementation of these policies, since most consumers in India and some frugal markets have outdated appliances that are unintelligent with a severe need to develop low- cost smart network-controllable solutions, these policies can improve the consumer's life in terms of cost saving over a longer term and serving green energy. These algorithms can have wide applications in the domestic sector, to help consumers take a decision on installation of solar PV and also for the auxiliary supply in substations. Solar plants can serve as a smarter alternative to the existing fuel based systems and can help reduce the carbon footprint on our planet.

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