Demand Side Management for a Campus Infrastructure

BATCH : A6

TYPE : IN-HOUSE

GUIDE : DR. SG BHARATHI DASAN

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1st Review

01 Introduction to DSM

02 Need for DSM

03 DSM Techniques

04 Literature survey

05 Problem Formulation

2nd Review

01 Overview

02 Objective Load Curve

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05 Simulation & Results

3rd Review

01 Overview

02 Campus Data Analysis

03 Average Load Technique

04 Simulation Results

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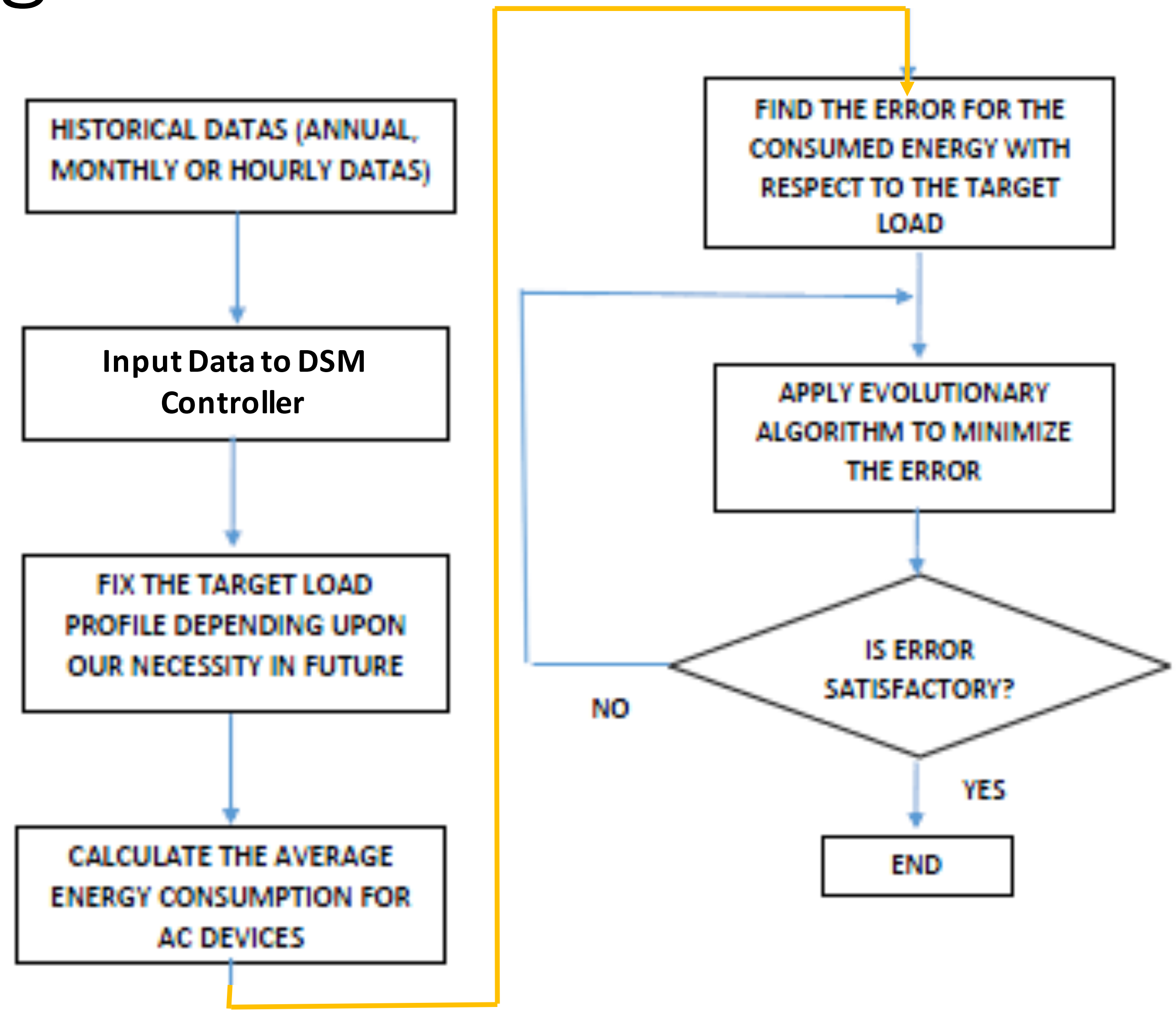
Block Diagram



CAMPUS LOAD STUDY

Period - (24 Hrs)

1. Mechanical
2. Electrical
3. Computer Science
4. Marine
5. ECE & Civil
6. Mechanical Workshop
7. Air Conditioners – Overall
8. Canteen
9. Hostel
10. Library & Admin Block
11. Lighting Loads – Classrooms

Campus Load Study - Individual Departments - 15th March 2016

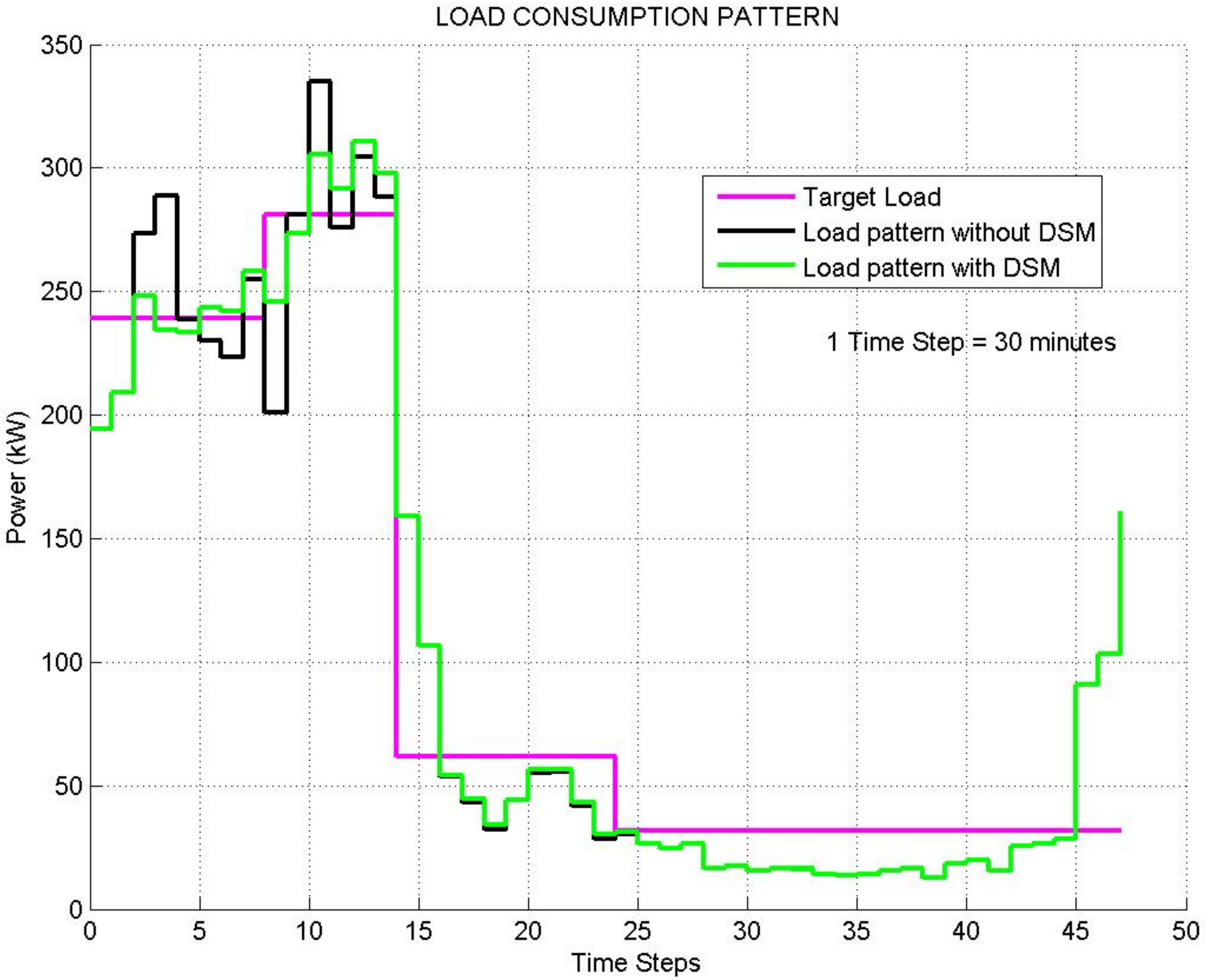
Time Stamp	PSMB 1 & 4			PSMB 2			PSMB 3			PSMB 12		
	EEE Dept			MEC Dept			CSE Dept			MR Dept		
	R Phase	Y Phase	B Phase	R Phase	Y Phase	B Phase	R Phase	Y Phase	B Phase	R Phase	Y Phase	B Phase
9:00:00 AM	5.00	12.50	10.00	16.60	5.00	20.00	51.00	47.20	52.00	47.00	75.00	60.00
9:30:00 AM	6.00	27.00	133.00	15.00	0.00	17.00	60.00	44.40	61.60	50.00	88.00	75.00
10:00:00 AM	5.00	45.00	12.00	18.00	0.00	20.00	57.50	47.10	62.60	75.00	150.00	80.00
10:30:00 AM	4.00	15.00	19.00	18.00	0.00	30.00	63.70	48.70	60.20	50.00	140.00	85.00
11:00:00 AM	10.00	20.00	12.00	10.00	0.00	12.00	53.90	49.50	60.40	78.00	135.00	90.00
11:30:00 AM	4.00	25.00	20.00	10.00	0.00	10.00	55.10	43.00	57.60	75.00	140.00	100.00
12:00:00 PM	10.00	26.00	25.00	10.00	0.00	25.00	41.00	31.80	49.20	75.00	150.00	125.00
12:30:00 PM	5.00	38.00	18.00	10.00	0.00	10.00	41.20	31.20	48.20	70.00	150.00	112.00
1:00:00 PM	5.00	25.00	15.00	40.00	0.00	40.00	50.10	40.70	65.80	80.00	160.00	120.00
1:30:00 PM	20.00	40.00	35.00	66.00	5.00	66.00	49.50	52.20	66.80	100.00	145.00	110.00
2:00:00 PM	25.00	50.00	38.00	35.00	0.00	35.00	53.30	41.70	64.90	105.00	125.00	110.00
2:30:00 PM	20.00	50.00	25.00	25.00	0.00	40.00	53.90	46.40	63.30	85.00	120.00	130.00
3:00:00 PM	10.00	20.00	20.00	30.00	0.00	13.00	52.50	45.90	62.00	55.00	120.00	125.00
3:30:00 PM	10.00	50.00	25.00	0.00	0.00	0.00	34.70	31.70	34.30	35.00	75.00	85.00
4:00:00 PM	5.00	37.50	17.50	0.00	0.00	0.00	20.85	20.35	22.05	17.50	37.50	46.25
4:30:00 PM	0.00	25.00	10.00	0.00	0.00	0.00	7.00	9.00	9.80	0.00	0.00	7.50
5:00:00 PM	0.00	17.50	5.00	0.00	0.00	0.00	7.05	9.15	10.00	0.00	0.00	7.50
5:30:00 PM	0.00	10.00	0.00	0.00	0.00	0.00	7.10	9.30	10.20	0.00	0.00	7.50
6:00:00 PM	5.00	10.00	0.00	0.00	0.00	0.00	6.90	9.35	10.15	12.50	0.00	3.75
6:30:00 PM	10.00	10.00	0.00	0.00	0.00	0.00	6.70	9.40	10.10	25.00	0.00	0.00
7:00:00 PM	10.00	10.00	0.00	0.00	0.00	0.00	6.70	9.40	10.10	25.00	0.00	0.00
7:30:00 PM	5.00	5.00	0.00	0.00	0.00	0.00	7.20	9.50	10.35	12.50	0.00	0.00
8:00:00 PM	0.00	0.00	0.00	0.00	0.00	0.00	7.70	9.60	10.60	0.00	0.00	0.00

Distribution Transformer Data

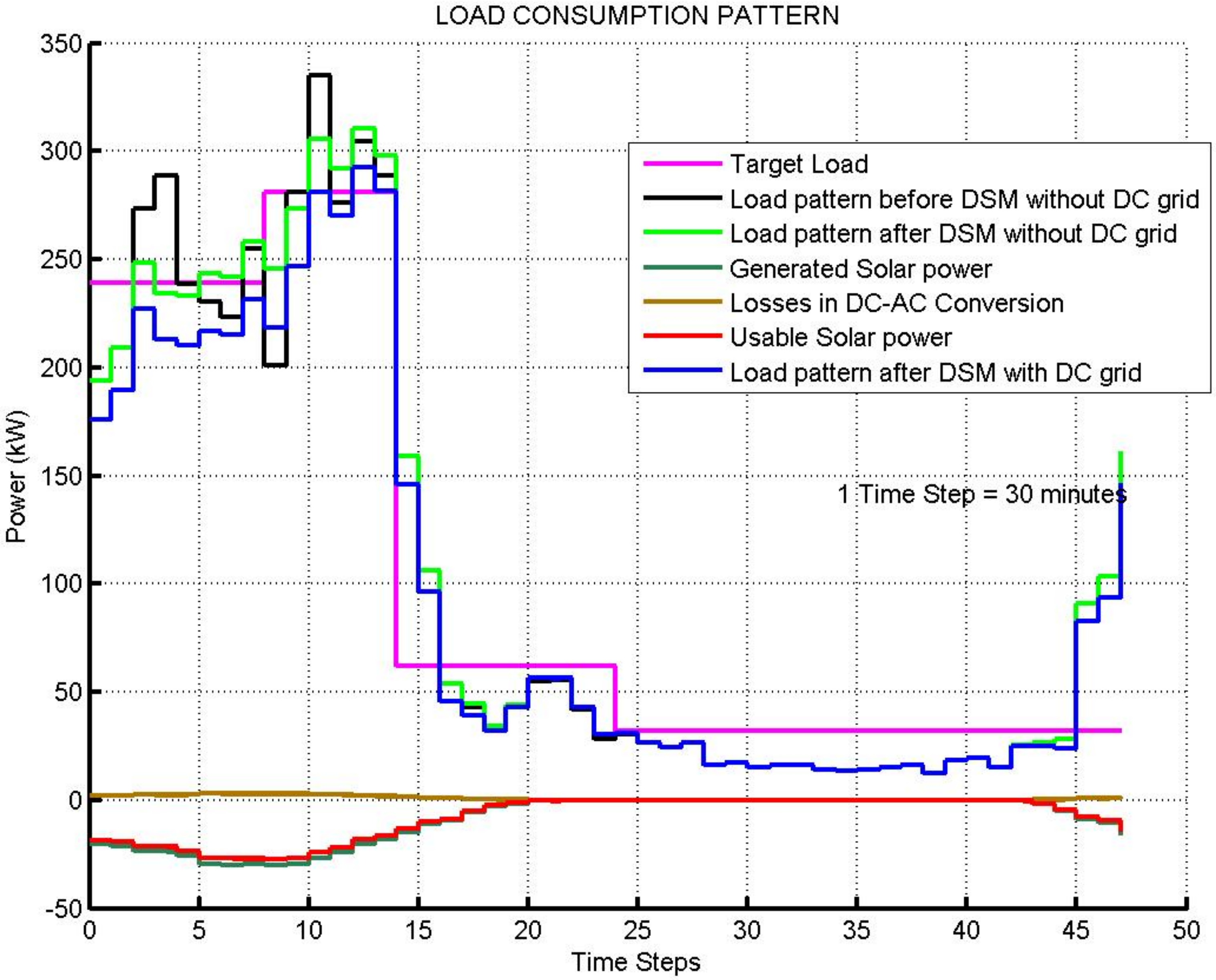
Period - (24 Hrs)

Time Stamp	Panel 1			Panel 2			Panel 3			Total
	TRANSFORMER 1			TRANSFORMER 2			TRANSFORMER 3			
	R Phase	Y Phase	B Phase	R Phase	Y Phase	B Phase	R Phase	Y Phase	B Phase	
9:00:00 AM	138.00	173.00	173.00	200.00	30.00	225.00	322.10	338.70	312.10	1911.90
9:30:00 AM	152.00	187.00	172.00	340.00	30.00	325.00	391.00	371.00	337.00	2305.00
10:00:00 AM	169.00	237.00	183.00	210.00	120.00	235.00	394.90	372.00	357.40	2278.30
10:30:00 AM	149.00	205.00	179.00	200.00	120.00	210.00	379.00	330.00	331.60	2103.60
11:00:00 AM	143.00	218.00	175.00	200.00	80.00	200.00	378.00	328.00	337.00	2059.00
11:30:00 AM	130.00	214.00	160.00	220.00	25.00	220.00	375.50	313.90	327.90	1986.30
12:00:00 PM	162.00	244.00	206.00	190.00	10.00	200.00	365.70	321.40	322.30	2021.40
12:30:00 PM	181.00	260.00	235.00	180.00	10.00	180.00	390.50	356.30	352.10	2144.90
1:00:00 PM	206.00	230.00	245.00	200.00	20.00	200.00	385.10	388.00	368.80	2242.90
1:30:00 PM	214.00	235.00	205.00	225.00	25.00	225.00	425.50	421.60	385.10	2361.20
2:00:00 PM	256.00	252.00	240.00	210.00	15.00	215.00	372.60	365.70	318.60	2244.90
2:30:00 PM	220.00	240.00	265.00	230.00	15.00	230.00	390.00	375.30	333.60	2298.90
3:00:00 PM	205.00	227.00	246.00	210.00	20.00	240.00	367.20	372.00	334.00	2221.20
3:30:00 PM	150.00	220.00	166.00	150.00	10.00	150.00	235.30	240.20	205.70	1527.20
4:00:00 PM	98.50	140.00	122.00	125.00	10.00	135.00	159.20	156.50	139.55	1085.75
4:30:00 PM	47.00	60.00	78.00	100.00	10.00	120.00	83.10	72.80	73.40	644.30
5:00:00 PM	40.50	45.00	70.00	110.00	10.00	120.00	74.35	65.35	73.45	608.65
5:30:00 PM	34.00	30.00	62.00	120.00	10.00	120.00	65.60	57.90	73.50	573.00
6:00:00 PM	45.50	15.00	48.00	150.00	15.00	160.00	71.78	68.90	75.65	649.83
6:30:00 PM	57.00	0.00	34.00	180.00	20.00	200.00	77.96	79.90	77.80	726.66
7:00:00 PM	57.00	0.00	34.00	180.00	20.00	200.00	77.96	79.90	77.80	726.66
7:30:00 PM	41.00	9.50	42.00	165.00	20.00	175.00	61.43	69.05	79.70	662.68
8:00:00 PM	25.00	19.00	50.00	150.00	20.00	150.00	44.90	58.20	81.60	598.70

Without DC Grid



With DC Grid



Existing 35KW Solar Power

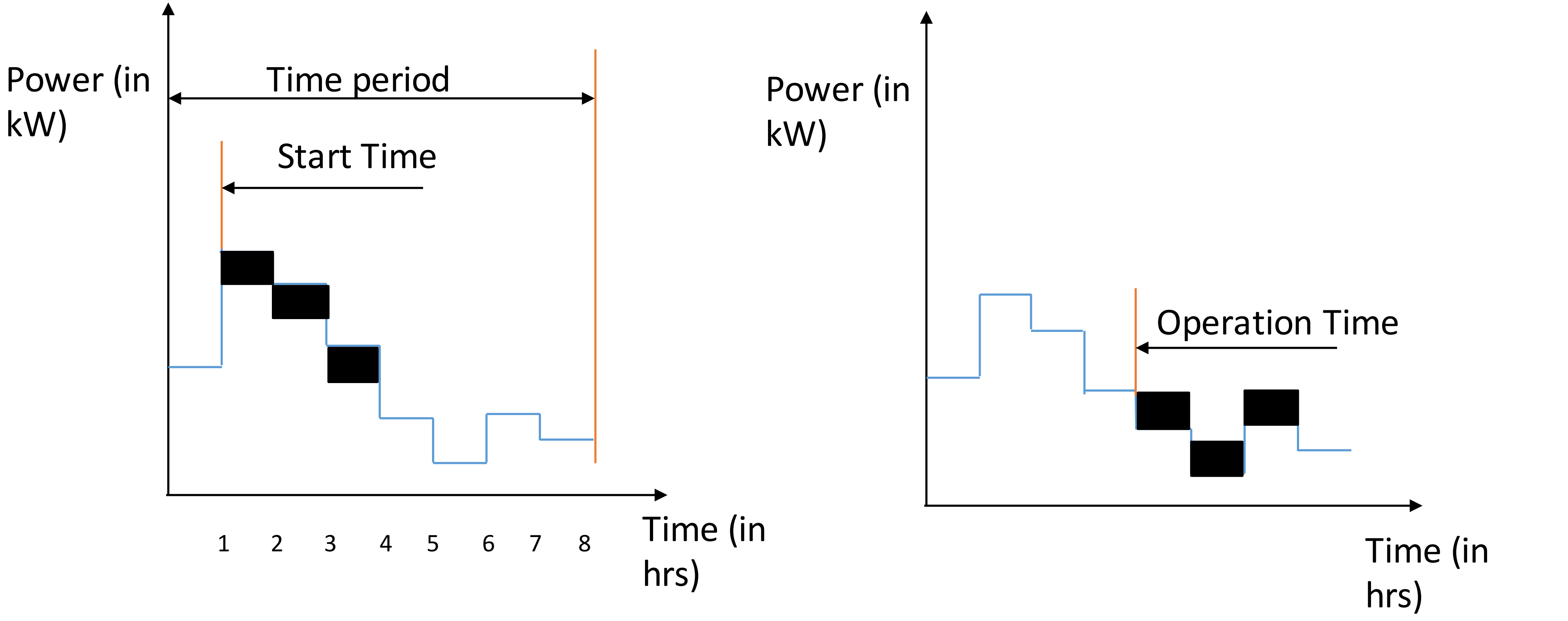
Methodology

- Parameters Involved

  - Device Type
  - Device Number
  - Delay parameter
  - Consumption period
  - Power rating of a particular device
  - Actual Start time
  - Operation time

VARYING PARAMETER

- Variable in load shifting technique – DELAY
- Assume Delay=4 hours



Proposed load shifting technique is mathematically formulated as follows.

- $$\sum_{t=1}^{N} (PLoad(t) - Objective(t))^2$$
  - Where Objective(t) is the value of the objective curve at time t
  - PLoad(t) is the actual consumption at time t.
- . $$Objective(t) = \frac{Pload_{avg}}{Pload_{\max}} \times \frac{1}{Pload(t)} \times \sum_{s=1}^{24} Pload(s)$$
- ***Average Load Curve Fitting***
  - Education institution follows flat tariff for electricity.
  - Tracking dynamic pricing is difficult in this scenario
  - Hence, we divide the time period into four phases.
  - The Average is calculated for the each phase.
  - Average Load = (Load factor) * (Maximum Demand)

- ***PLoad(t)=Forecast(t)+Connect(t)+Disconnect(t)***

  - Where Forecast(t) is the forecasted consumption at time t ,and
  - Connect(t) and Disconnect(t) are the amount of loads to be connected and disconnected at time t respectively during the load shifting.

- *Connect(t) is made up of two parts:*
  - *The increment in the load at time t due to the connection times of devices shifted to time t.*
  - *The increment in the load at time t due to the device connections scheduled for times that precede t.*
- $$\textbf{Connect(t)}= \sum_{i=1}^{N} \sum_{k=1}^{D} X_{kit}.P_{1k} + \sum_{l=1}^{j-1} \sum_{i=1}^{t-1} \sum_{k=1}^{D} X_{ki(t1)}P_{(1+l)k}$$
  - Where X_{kit} is the number of devices of type that are shifted from time step i to t.
  - D is the number of device types, P_{1k} and $P_{(1+l)k}$ are the power consumptions at time steps 1 and (1+l)

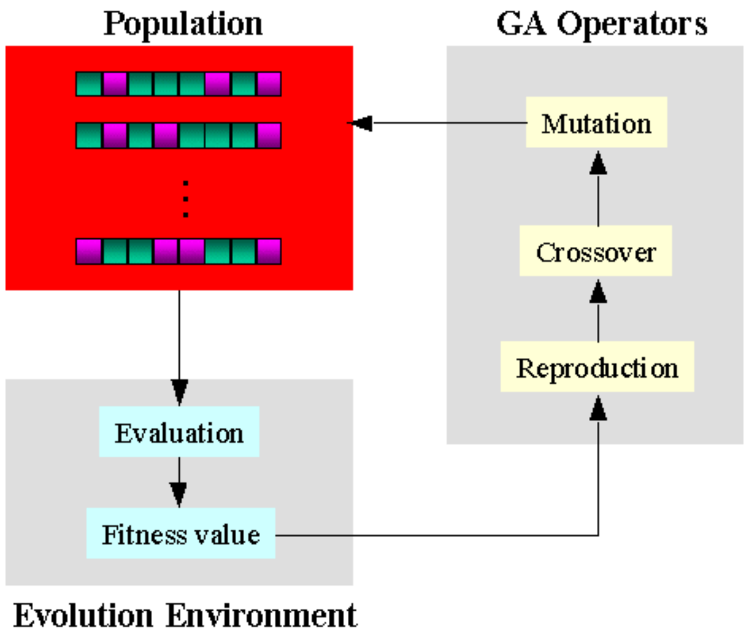
- Similarly ,Disconnect() also consists of two parts:
  - The decrement in the load due to delay in connection times of devices that were originally supposed to begin their consumption at time step t.
  - The decrement in the load due to delay in connection times of devices that were expected to start their consumption at time steps that precede t.
- $$\textbf{Disconnect(t)}= \sum_{q=t+1}^{t+m} \sum_{k=1}^{D} X_{kqt}.P_{1k} + \sum_{l=1}^{j-1} \sum_{q=t+1}^{t+m} \sum_{k=1}^{D} X^{kq(t-1)}P_{(1+l)k}$$
  - Where X_{ktq} is the number of devices of type that are delayed from time step t to q
  - m is the maximum allowable delay.

- The number of devices shifted cannot be a negative value.
  - **X_{kit} > 0 for all i,j,k.**
- The number of devices shifted away from a time step cannot be more than the number of devices available for control at the time step.
  - **$\sum_{t=1}^{N} X_{kit}$ <= Ctrlable(i)**
  - Where Ctrlable(i) is the number of devices of type k available for control at time step i.

The Process Flow

In the genetic algorithm process is as follows:

- Step 1. Determine the number of chromosomes, generation, and mutation rate and crossover rate value
- Step 2. Generate chromosome-chromosome number of the population, and the initialization value of the genes chromosome-chromosome with a random value
- Step 3. Process steps 4-7 until the number of generations is met
- Step 4. Evaluation of fitness value of chromosomes by calculating objective function
- Step 5. Chromosomes selection
- Step 5. Crossover
- Step 6. Mutation
- Step 7. New Chromosomes (Offspring)
- Step 8. Solution (Best Chromosomes)



Genetic Algorithm Evolution Flow

Initialization

- The most common type of genetic algorithm works as follows
- A population is created with a group of individuals created randomly.
- The random no generation is possible with rand() function.
- The population is initialized keeping in account the **constraints** of the given problem.
- Chromosome is initialized based on the constraints with the help of following logic

$$\mathbf{chromosome(I,j)=\sum_{i=1}^{n} \sum_{j=1}^{k} (A(j)+(B(j)-A(j))*rand())}$$

- NOTE: rand() generates values between 0 and 1

Evaluation and Selection…

- The fitness function of individuals in the population are then evaluated.

$$Fitness = \frac{1}{1 + \sum_{t=1}^{n} \left(PLoad\left(t\right) - Objective\left(t\right)\right)^2}.$$

(i=1->n)Prob(i)=$\sum_{i=1}^{n}(Fitness(i)/total)$, Here total= $\sum_{i=1}^{n} Fitness(i)$

(i=1->n) Cummprob(i)=$\sum_{i=1}^{n} Cummprob(i-1) + Prob(i)$

Ra=rand() [Random no is generated(0->1)]

```
if(Ra(i)<cummprob(j))      // Selection process..
        for m=1:k
           newc(i,m)=p(j,m);
```

The higher the fitness, the higher the chance of chromosome being selected.

Cross over

Three Steps involved in cross over

i).Parent Selection ii).N possibilities iii). Position for cross over

Step(i)

For k=1:n

R[k] ← random(0-1);

if (R[k] < ρc) then

select Chromosome[k] as parent;

Step (ii):

For example: If three parents are selected then possibilities of crossover are,

Chromosome[1] >< Chromosome[4]

Chromosome[4] >< Chromosome[5]

Chromosome[5] >< Chromosome[1]

Step(iii)

m=floor((k-1)*rand()+1); (random no between 1 to (lengthofchromo-1)

for j=1:k

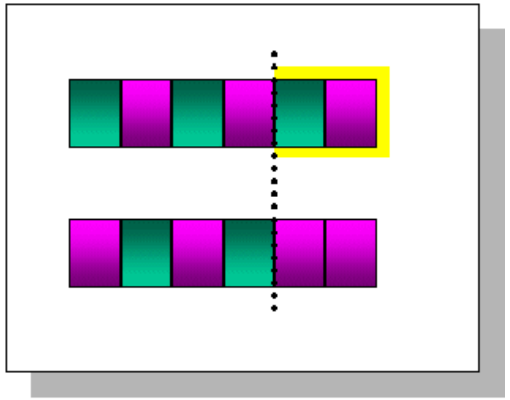
if(j<=m)

child(i,j)=parent(i,j);

else

child(i,j)=parent(i+1,j);

m points to position of crossover

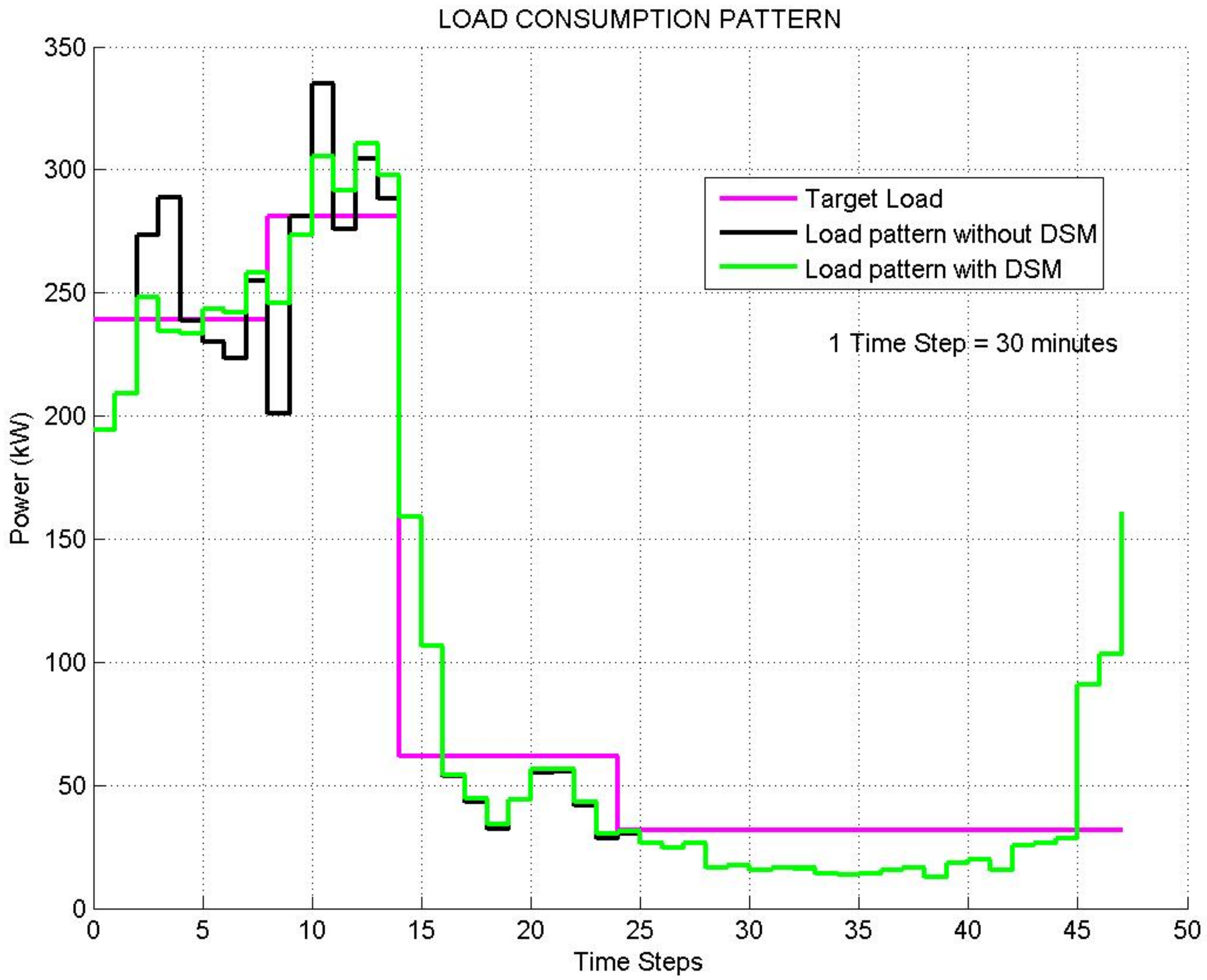


One-Point Crossover

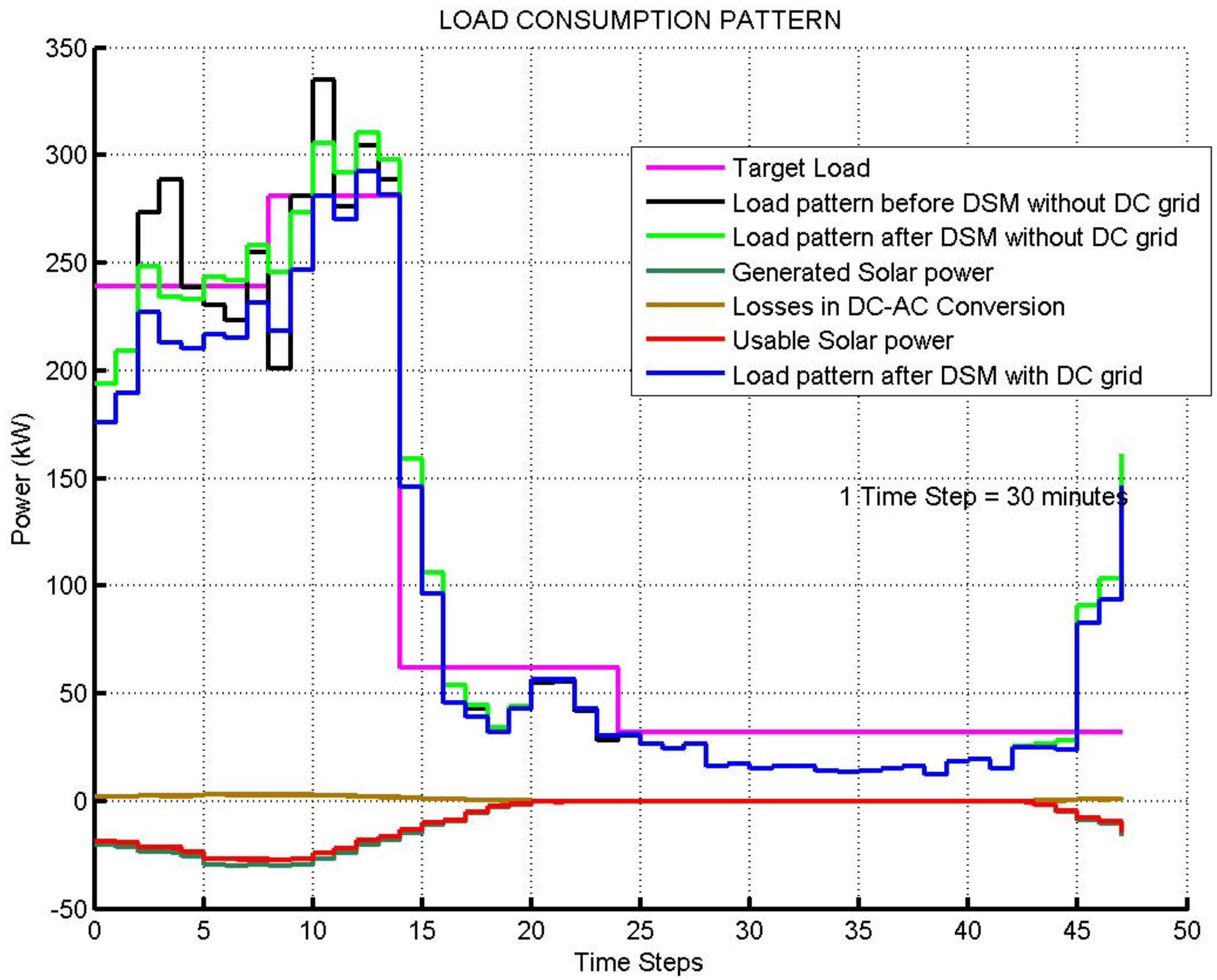
Mutation

- Total_gen(noe) = number_of_gen_in_Chromosome * number of population.
- mut=pm*noe; where pm is the mutation rate.
- totalmut=round(mut);
- pos=floor((1+(noe-1)*rand(totalmut,1)));
- The value of mutated gens at mutation point is replaced by random number.
- for m=1:totalmut
- if((i==row(m)) && (j==col(m)))
- newc(i,j)=s(j)+(r(j)-s(j))*rand();
- And after mutation process the next iteration starts and the process continues till we get the best chromosome…

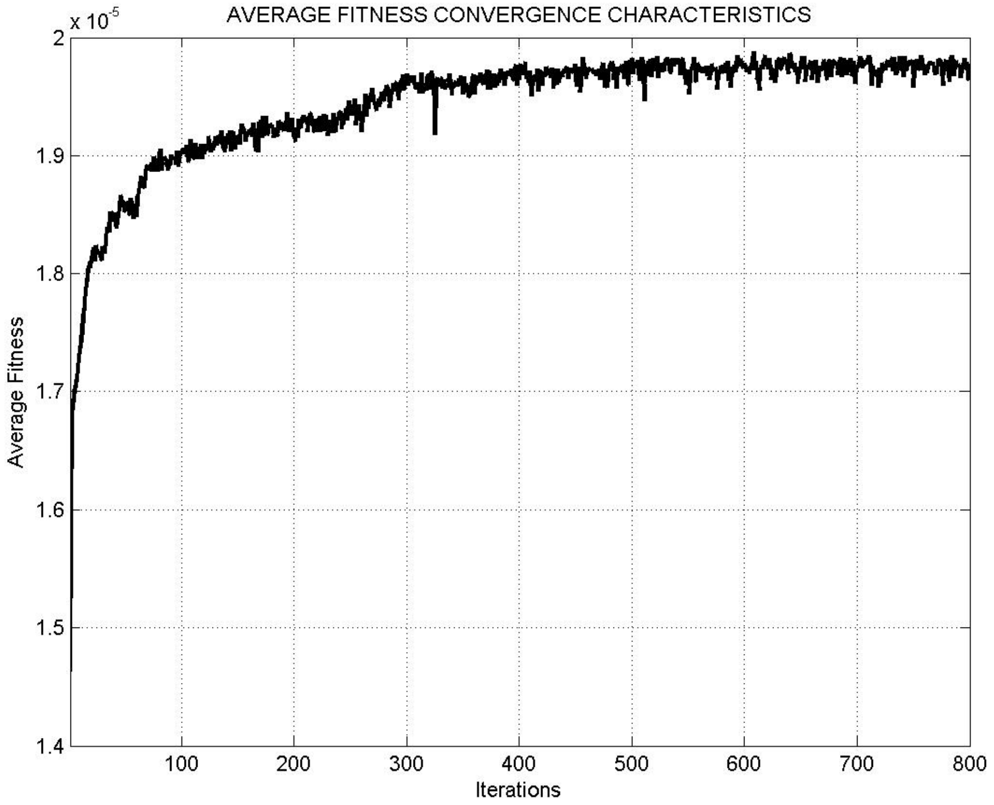
Simulation & Results

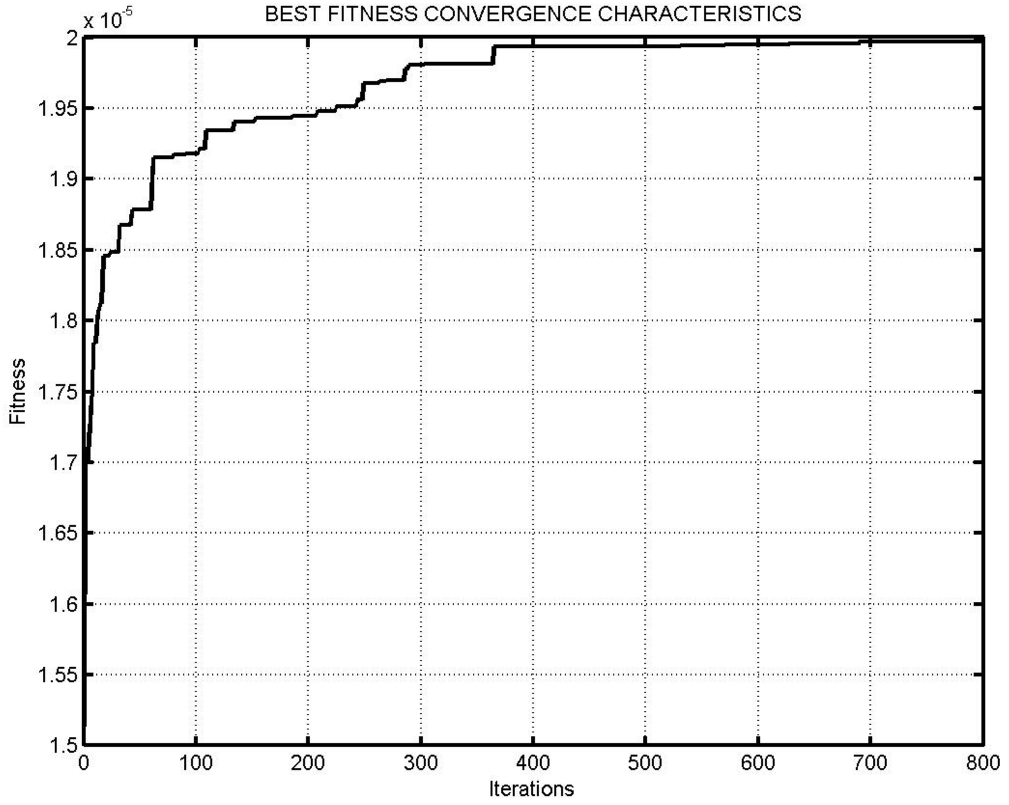


Simulation & Results



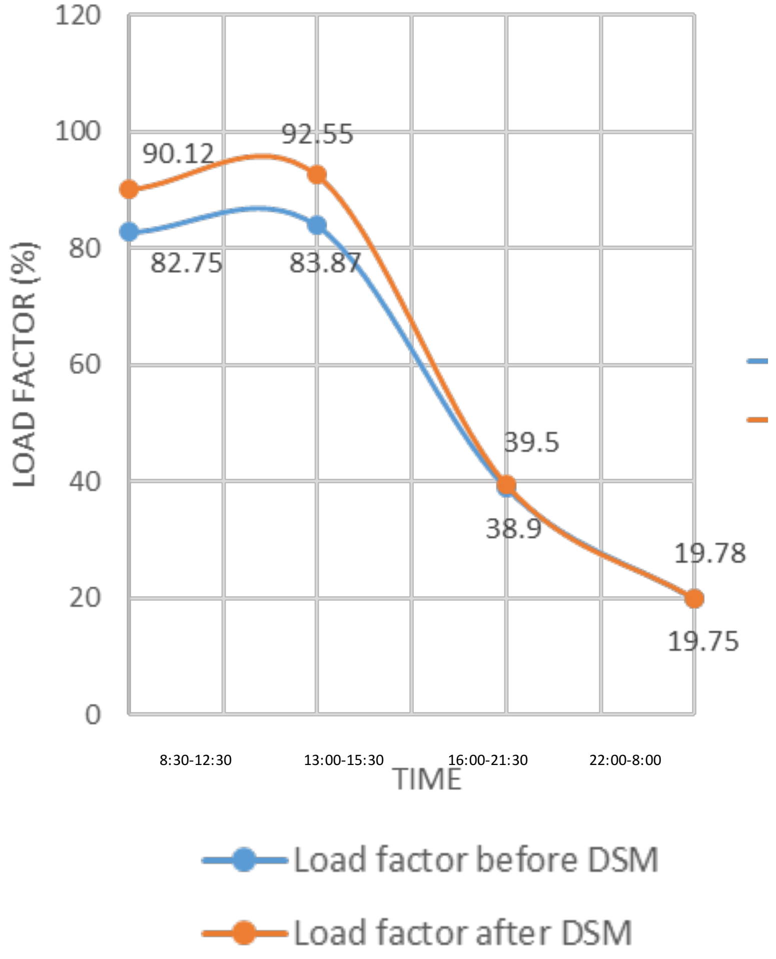
Simulation & Results





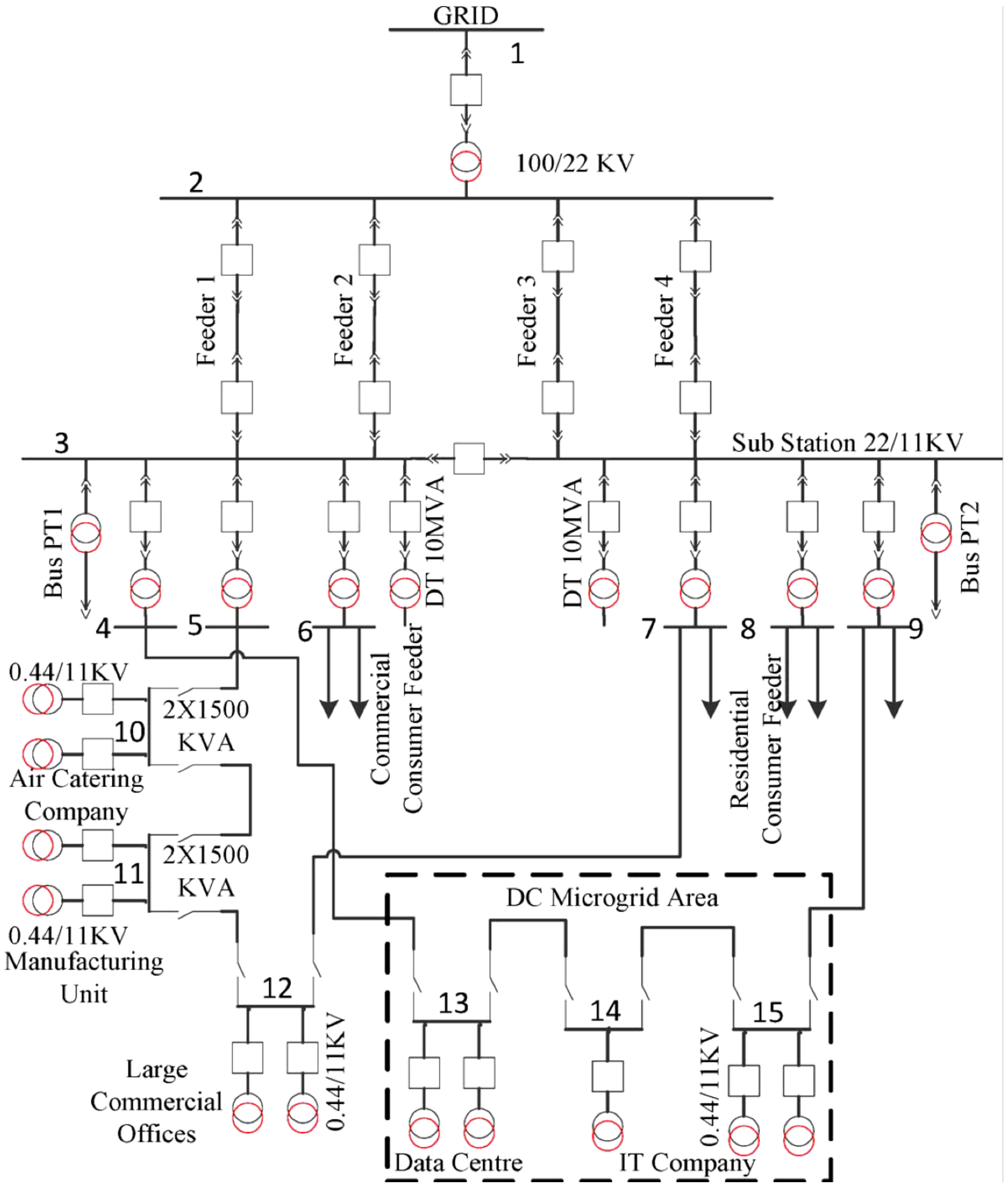
Simulation & Results

S No	Time	Load Factor before DSM (%)	Load Factor after DSM (%)	Peak reduction (%)	Over all Peak Reduction (%)	Overall Peak Reduction with DC Grid (%)
1	08:30 – 12:30	82.75	90.12	10.57	7.26	11.25
2	13:00 – 15:30	83.87	92.55	7.26		
3	16:00 – 21:30	38.90	39.50	0		
4	22:00 – 08:00	19.75	19.78	0		



Case Study

The system considered for simulation is from Mumbai, the capital city of Maharashtra state in India.

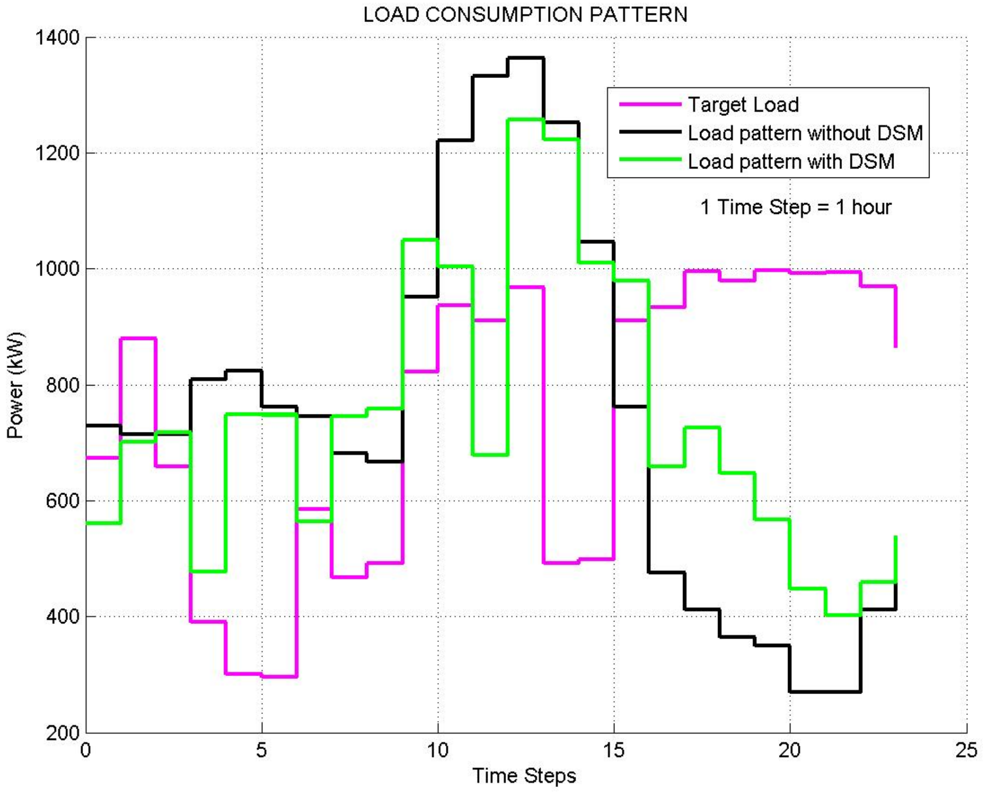


Case Study

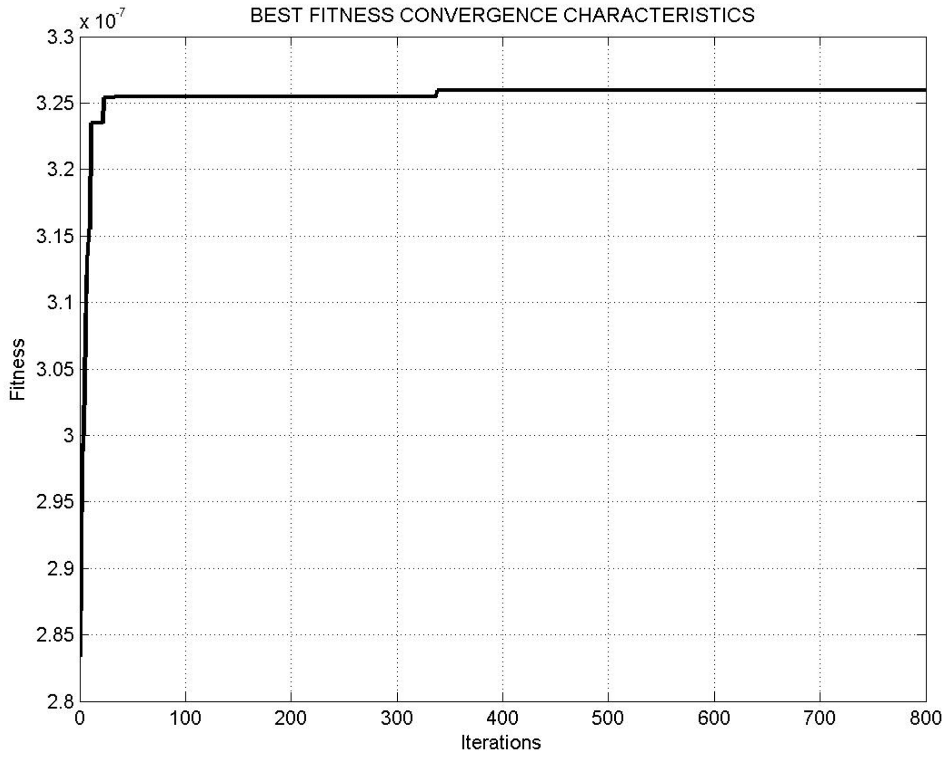
Time	Price	Hourly Forecasted Load (kW)	
		Residential	Industrial
08:00 – 09:00	12.00	729.4	2045.5
09:00 – 10:00	9.19	713.5	2435.1
10:00 – 11:00	12.27	713.5	2629.9
11:00 – 12:00	20.69	808.7	2727.3
12:00 – 13:00	26.82	824.5	2435.1
13:00 – 14:00	27.35	761.1	2678.6
14:00 – 15:00	13.81	745.2	2678.6
15:00 – 16:00	17.31	681.8	2629.9
16:00 – 17:00	16.42	667	2532.5
17:00 – 18:00	9.83	951.4	2094.2
18:00 – 19:00	8.63	1220.9	1704.5
19:00 – 20:00	8.87	1331.9	1509.7
20:00 – 21:00	8.35	1363.6	1363.6
21:00 – 22:00	16.44	1252.6	1314.9
22:00 – 23:00	16.19	1046.5	1120.1
23:00 – 00:00	8.87	761.1	1022.7
00:00 – 01:00	8.65	475.7	974
01:00 – 02:00	8.11	412.3	876.6
02:00 – 03:00	8.25	364.7	827.9
03:00 – 04:00	8.10	348.8	730.5
04:00 – 05:00	8.14	269.6	730.5
05:00 – 06:00	8.13	269.6	779.2
06:00 – 07:00	8.34	412.3	1120.1
07:00 – 08:00	9.35	539.1	1509.7

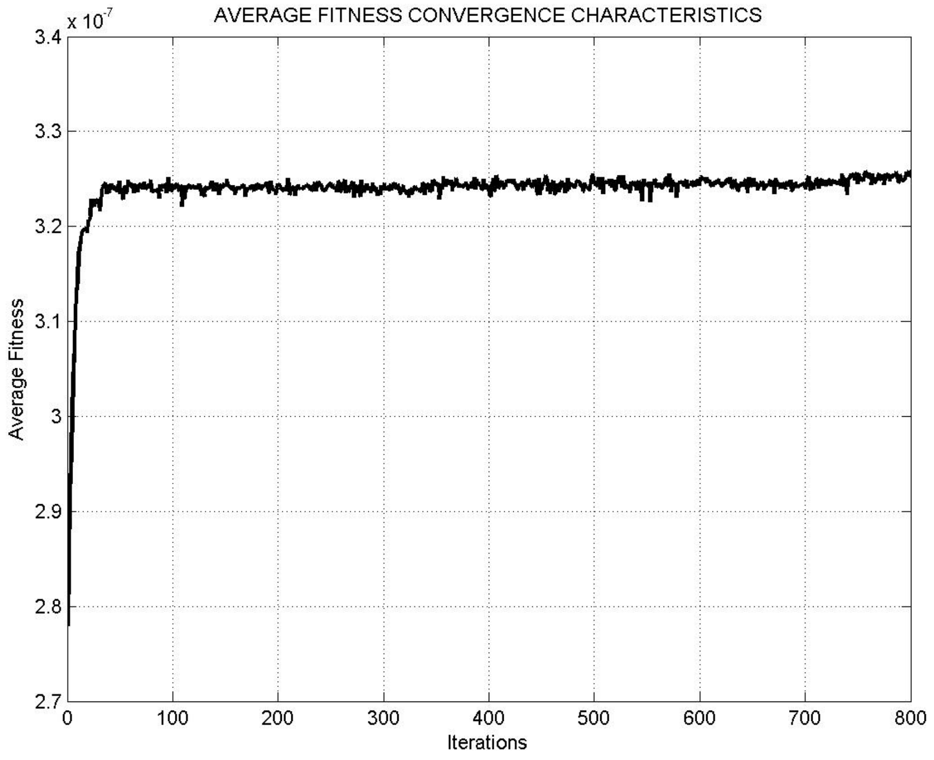
Case Study – Residential Area

Device Type	Hourly Consumption of Device (kW)			Number of Devices
	1st Hr	2nd Hr	3rd Hr	
Dryer	1.2	-	-	189
Dish Washer	0.7	-	-	288
Washing Machine	0.5	0.4	-	268
Oven	1.3	-	-	279
Iron	1.0	-	-	340
Vacuum Cleaner	0.4	-	-	158
Fan	0.20	0.20	0.20	288
Kettle	2.0	-	-	406
Toaster	0.9	-	-	48
Rice-Cooker	0.85	-	-	59
Hair Dryer	1.5	-	-	58
Blender	0.3	-	-	66
Frying Pan	1.1	-	-	101
Coffee Maker	0.8	-	-	56
Total	-	-	-	2604



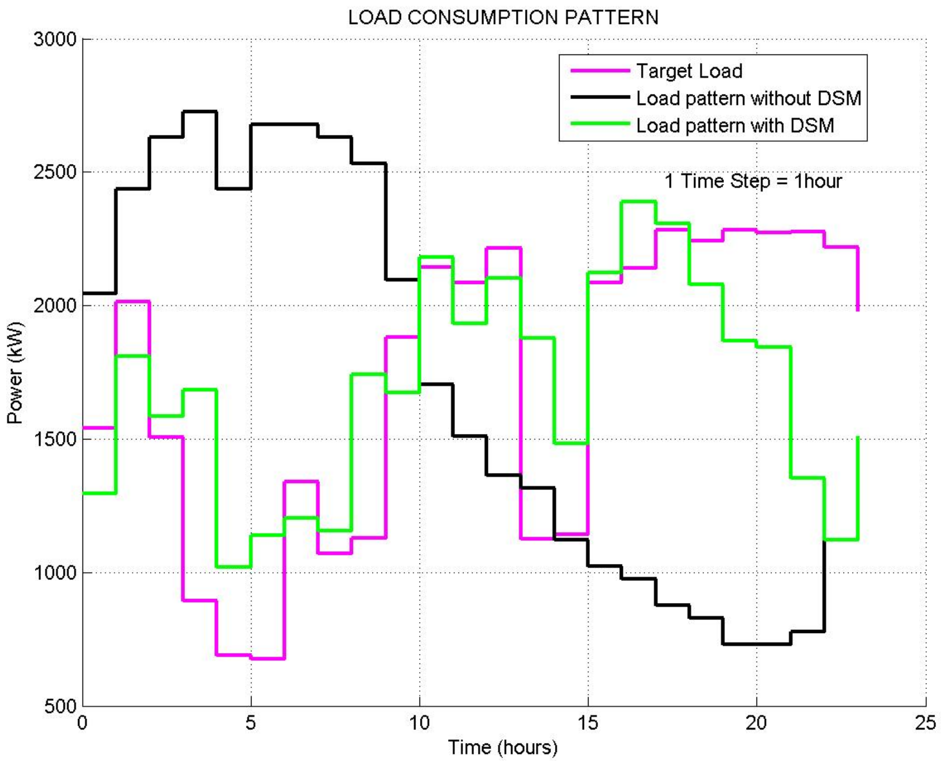
Residential Area – Convergence Characteristics



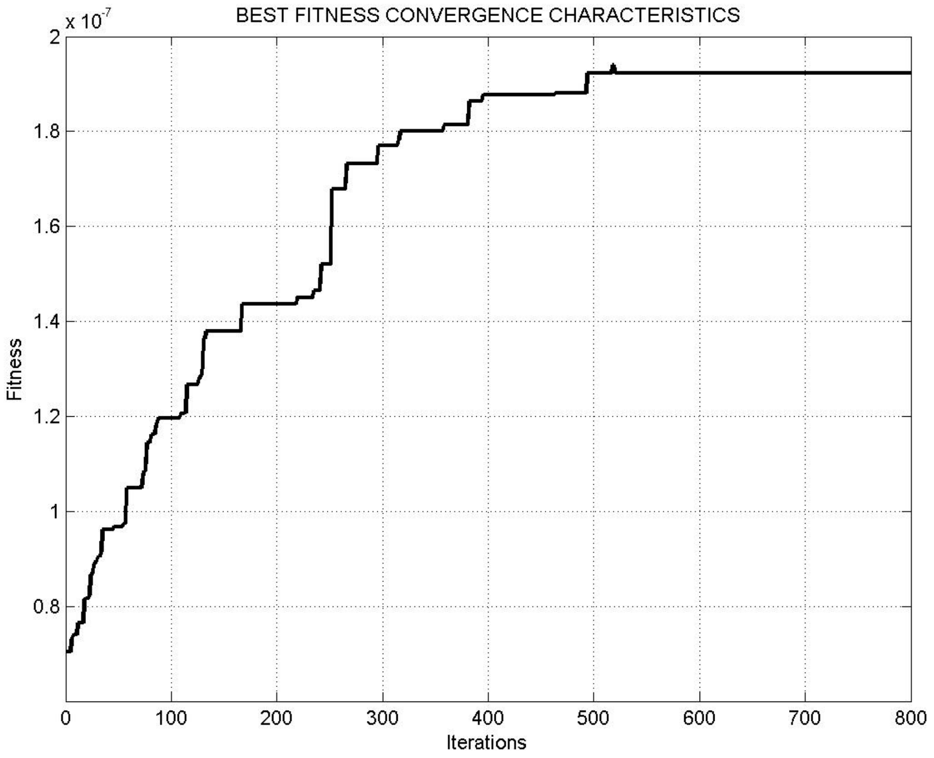


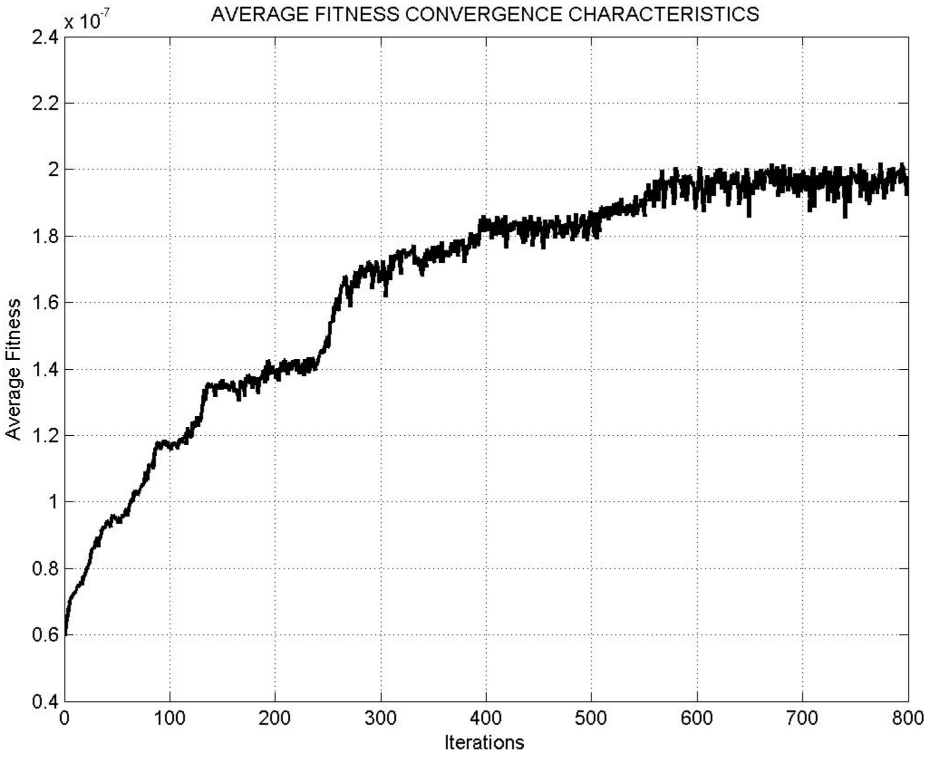
Case Study – Industrial Area

Device Type	Hourly Consumption of Device (kW)						Number Devices
	1st Hr	2nd Hr	3rd Hr	4th Hr	5th Hr	6th Hr	
Water Heater	12.5	12.5	12.5	12.5	-	-	39
Welding Machine	25.0	25.0	25.0	25.0	25.0	-	35
Fan/AC	30.0	30.0	30.0	30.0	30.0	-	16
Arc Furnace	50.0	50.0	50.0	50.0	50.0	50.0	8
Induction Motor	100	100	100	100	100	100	5
DC Motor	150	150	150	-	-	-	6
Total	-	-	-	-	-	-	109



Industrial Area – Convergence Characteristics





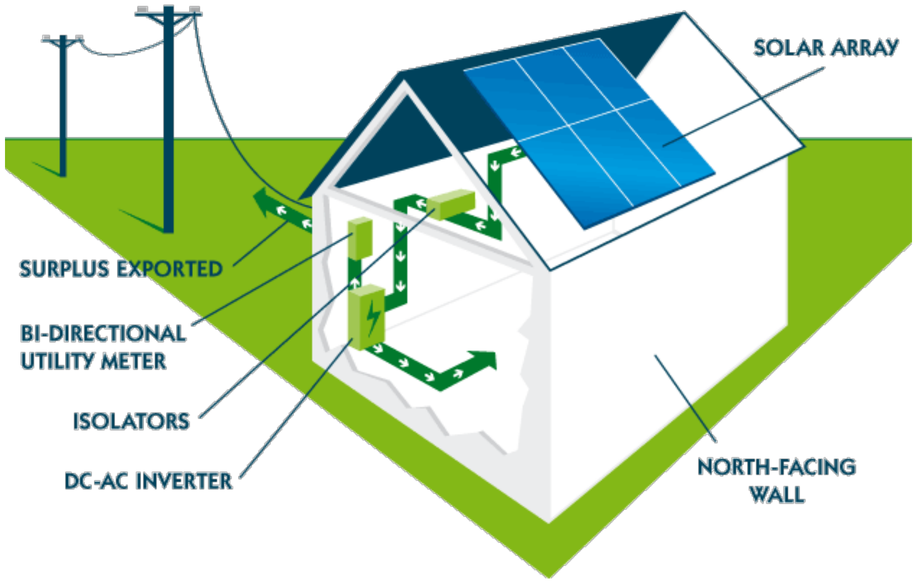
Result & Conclusion

- Cost Reduction with & without using DSM

	Residential	Industrial
Peak Reduction (%)	7.78	13.87
Cost without DSM (Rs)	230,300	571,200
Cost with DSM (Rs)	223,420	476,200
Cost Reduction (%)	2.98	16.62

Contribution to the Society:

- **Smartness**: Effectively managing loads in a power grid by adopting intelligent DSM Controllers.
- **Smart Pricing**: Automatic metering that allows consumers to make informed decisions regarding their energy consumption, and peak load pricing.
- **Virtual Power Plant**: Voluntarily lowering consumers demand for electricity
- **Carbon Footprint**: Reduced greenhouse gas emissions.



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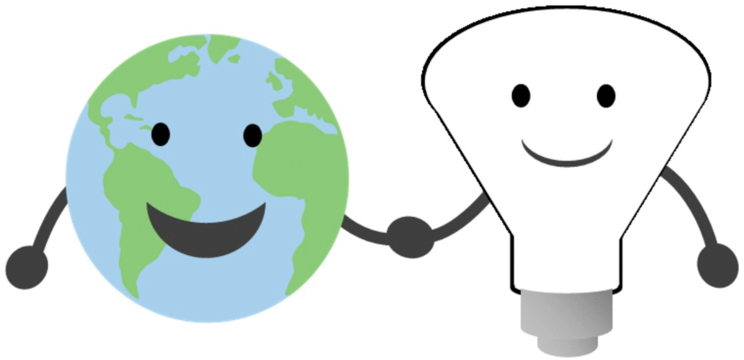

Thank You !!