Demand Response Program for consumer interactive distribution system

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***Abstract*—Energy is one of the most vital necessities or requirements whether it is consumption at home, utilization in an industry or any other service oriented organization. With the increasing need, the demand of energy too is increasing day by day however no major integration of renewable energy sources can be made out. By implementing Innovative Demand Response Management System Optimum utilization of existing resources can be done and hence gap between demand and supply can be minimized. Demand Response is essential for balancing the supply and demand relationship by shifting electricity demand from peak demand periods to off-peak demand periods and hence minimizes the electricity generation from fossil fuels and protect the environment. On the basis of the load forecasting, load curve is drawn and by implementing DR program, optimum scheduling of appliances is done with the help of LabVIEW which minimizes the cost of energy. Shifting of the load is done by considering Priority of load, Comfort level, Time of Use tariff, Flexibility, DR event. Survey is done for residential, commercial and industrial load and DR is implemented on these types of loads too.**

Keywords—Demand Response, Home Energy Controller (HEC), LabVIEW, Time of use (TOU), Grphical user Interface (GUI), Home Area Network (HAN)

I. INTRODUCTION

Demand Response (DR) can be defined as "changes in electric usage by the end user consumers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is in danger [1]."

By implementing DR, consumers can shift their shift able loads themselves or by the utility, at peak demands. Peak shaving during peak demands helps utility reduces outages, expenses on installation, running costs and alleviate major grid failures. With the advanced Information and communication tools and software, two way communications is possible which helps the consumer to manage their load to reduce the energy cost.

Following Technologies are used in Demand Response:

Consumer Interfaces: Utilities send signals to the participants of Demand Response program using different channels, such as email, cell phone, and web portals. In-home energy displays are another way that utilities can communicate with consumers about an event, including information about energy usage and dynamic pricing with smart grid. Consumers need to acknowledge their participation in the program. Home Area Network (HAN) can be used to connect displays, load control devices and smart appliances into the smart metering system.

Home Energy Controller (HEC): Utilities use a number of different regulators or thermostats to loads like heating and cooling during demand response events. Energy controller provides direct remote control over AC units or heating systems. Smart thermostats allow utilities to adjust temperature settings remotely.

AMI (Automatic Metering Infrastructure): AMI is increasingly being used with demand response to optimize the performance of DR, because it helps both utilities and end-users to have two- way communication, live data about loads, energy usage and electricity pricing can be displayed.

In this paper DR is performed in a home which shows how shift able loads can be shifted to off peak periods for peak shaving. By changing the thermostat set point of controllable loads energy consumption can be reduced.

An Algorithm is used in which load priority, comfort level, DR event, flexibility and TOU (Time of Use) is taken into consideration [5]. The shift able appliances used in this algorithm are Washing Machine, Flour mill, Water heater and Water Pump. This algorithm keeps the total household consumption below certain limit which is known as DR limit. There are three main types of load in a residence.

Must-on load: This type of load should remain on and cannot be switched off or shifted to other time period for peak shaving [3].

Controllable load: This type of load has thermostat to control the temperature which ultimately can change the energy consumption [3].

Shift able load: This type of load can be shifted to any other time slot at the time of high energy prices to reduce the energy cost. These types of appliances are used in peak shaving [3].

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For shifting the load we have to consider the following parameters:

TOU tariff: TOU tariff has number of different blocks for price. In our case the day is divided into two blocks. Peak period and off peak period.

DR event: This is the duration during which load has to be curtailed or shifted to reduce the Peak. The external signal is given through smart meters via email or SMS to the consumers about the DR Event. It also mentions the threshold value of the energy consumption which is also known as DR limit.

Priority of load: Consumers decide the priority according to which different shift able appliances should be shifted to any other time slots. The appliances with highest priority should be switched off at last.

Comfort level: Comfort level is the range of temperature in which consumer allow the controllable appliances to operate. Air conditioner is considered as a controllable appliance. We can adjust the temperature (by changing the thermostat setting) to change the energy consumption. Hence to reduce the peak we can change the thermostat setting without affecting the comfort level. Variation of room temperature by 2 degree from the original set point is defined as a comfort level.

Flexibility: In flexibility criteria, consumers specify the time period during which the particular appliance should be switched ON if it was switched OFF during DR event. This reduces the inconvenience to the consumer due to shifting of the appliances.

II. PROPOSED CONTROLLING SCHEME

In this algorithm comfort level of the consumer should not be violated during DR event. Any Violation from demand limit is the decision factor for switching OFF the appliances according to the set priority [2]. DR limit decides this factor.

A. Load Priority: Priority can be decides by the consumer beforehand. It can be changed when consumer wish to change.

TABLE: 1

Sr.No.	Priority and Preference setting of the Appliances		
	Name of appliance	***Priority***	***Preference setting***
1	Water Heater	1	Water temperature: 105-120□ F
2	Water Pump	2	Fill the required amount of water in one hour
3	Flour Mill	3	Should run continuously for one hour
4	Washing machine	4	Should not stop in between the middle of the operating cycle

B. Flexibility:

TABLE: 2

Sr.No.	Flexibility setting of the Appliances	
	Name of appliance	***Time Duration***
1	Water Heater	19:00 To 22:00
2	Water Pump	16:00 to 18:00
3	Flour Mill	18:00 to 21:00
4	Washing machine	18:00 To 20:00

Controlling Scheme for Washing Machine:

Washing machine should run continuously for one hour and cannot be stopped in middle of its operating cycle. It has the lowest priority. That means it should be the first to switch off. And if it is switched off during DR event it can be switched on again only during prescribed flexibility duration.

Controlling Scheme for Flour mill:

Flour mill should remain ON for an hour continuously. And if it is switched off during DR event it can be switched on again only during prescribed flexibility duration.

Controlling Scheme for Water Pump:

Water pump should remain ON till the required amount of water is filled in the tank. The minimum run time is one hour. And if it is switched off during DR event it can be switched on again only during prescribed flexibility duration.

Controlling Scheme for Water Heater:

Water heater should remain ON till the temp remains in comfort Range. Any comfort level Violation makes the water heater to remain ON to keep the water temperature within the specified limit. And if it is switched off during DR event it can be switched on again only during prescribed flexibility duration.

HEC Load Management strategy:

HEM collects all the information regarding total energy consumption, priority, comfort level temperature, flexibility and status of the appliances [5]. The comfort level decided by the consumer is the variation of 2 degree from the set point. If there is no comfort level violation and demand limit is less than total energy consumption, status of the appliance does not require to be changed. And if total consumption is more than DR limit and no comfort level violation then starting from the last priority one by one load are made OFF to make the total consumption below DR limit. We have also considered the flexibility customer has provided for shifting the appliances at particular time duration. This avoids the inconvenience to the consumer due to shifting of the appliance. In this strategy we have not curtailed the load of the consumer instead we have just shifted the load at specified duration. To reduce the total energy consumption of home, we can raise the temperature of thermostat within comfort level range. This can reduce the energy cost to the consumer. For A.C. modeling Cool Pack

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software is used which plots a graph showing the relationship between temperature and time that is helpful to find the energy consumption of A.C.

III. SURVEY FOR RESIDENTIAL, COMMERCIAL AND INDUSTRIAL LOADS

Survey is done for the residential load, Commercial load, water supply load and industrial load. Using the data, Load curve is drawn for all the houses. Load profile of all the individual appliances is also drawn for 24 hours. Load profile of controllable appliances changes with the thermostat setting.

For commercial load Flour mill and water supply load is considered in which load is shifted during no load period.

For industrial load data is collected from one industry which manufactures switchgear products and having different machines having ratings from 0.5 hp to 20 hp capacity. In this industry some load is shifted from peak period (first shift) to off- peak period (second or third shift) to reduce the peak.

IV. RESULTS AND GRAPHS

A. *Residential load:*

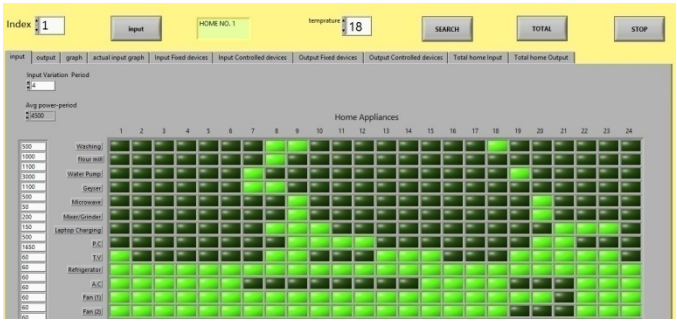

Fig.1. GUI shows residential load status

Fig.1 shows the GUI which is drawn in LabVIEW for residential load [6]. Index is used for selecting home, Display for home number, status of appliances before implementation of DR, status of appliances after DR, Temperature set point of thermostat of A.C., Total represents load of surveyed home before and after DR program.

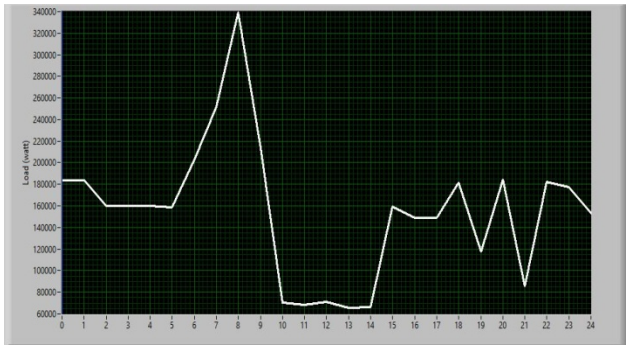

Fig.2. Residential load before shifting

Fig. 2 shows the residential load before DR program. We can see that the peak load is 340kw. By implementation of DR program peak can be reduced and load is shifted to off peak periods for energy cost saving. DR limit is taken as 280kw.

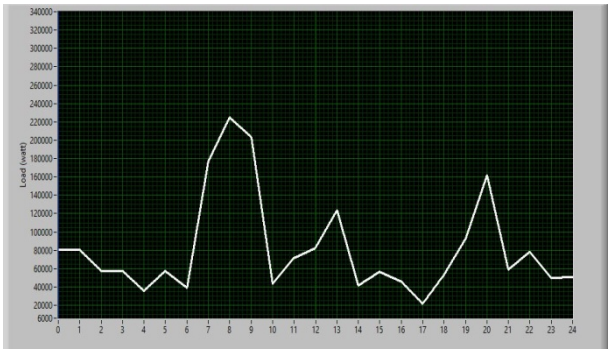

Fig.3. Residential load after shifting

Fig.3 shows Residential load after shifting. We can see that peak is reduced to 230kw and some load is shifted to off peak periods during DR event. This reduces the energy cost to the consumers.

B. *Commercial load:*

Flour mill and water supply load is considered as commercial loads. There are two flour mills and operating time of those mills is shown in the GUI.

Fig.4. GUI for Flour Mill

Fig.4 represents the GUI for flour mill which shows the status of flour mills. DR limit is considered as 3000watt.

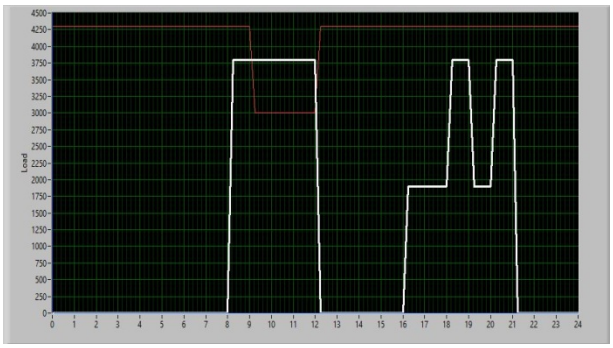

Fig.5. Flour mill load before shifting

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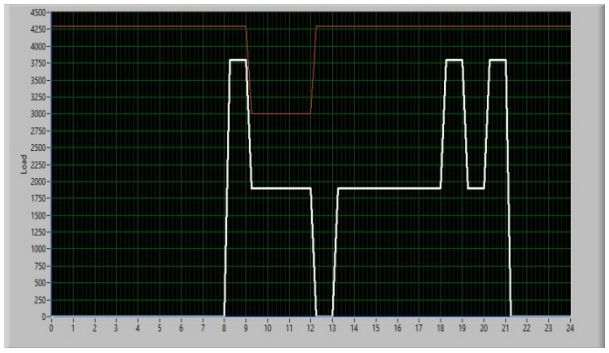

Fig.6 .Flour mill load after shifting

Fig. 5 and Fig. 6 represent the flour mill load before and after shifting. It shows the peak shaving during DR event which reduces the energy cost.

Same way water supply load can be represented.

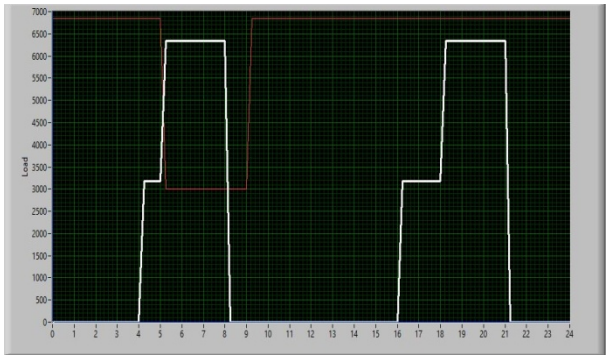

Fig.7. Water supply load before shifting

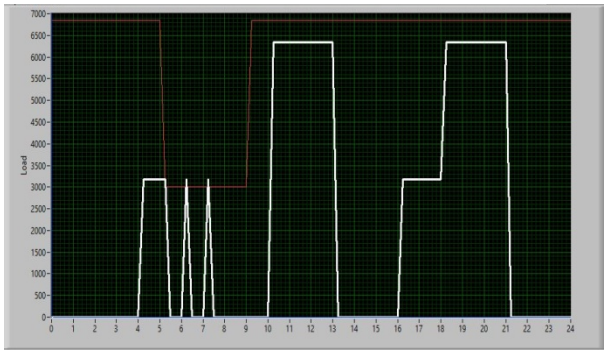

Fig.8. Water supply load before shifting

Fig.7 and Fig.8 represents the water supply load before and after shifting. In this case DR limit is taken as 3000watt.Red line shows the DR limit line. In this case also peak is shaved to reduce energy cost.

C. Industrial Load:

For industrial load energy consumption data is taken from an industry in which different machines of capacity ranging from 0.5hp to 20 hp is operating. This industrial load can be shifted from first shift to second or third shift to reduce energy cost. DR limit is taken as 80kw. Fig.9 and Fig.10 represent Industrial load before and after shifting.

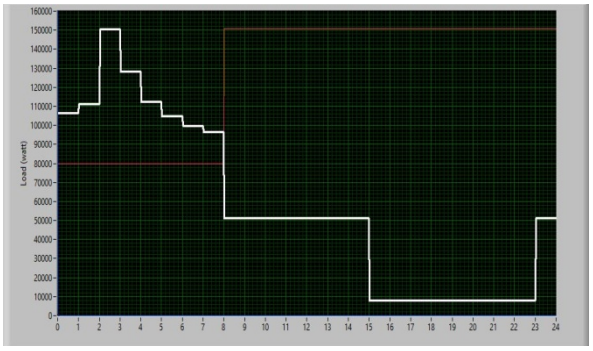

Fig.9. Industrial load before shifting

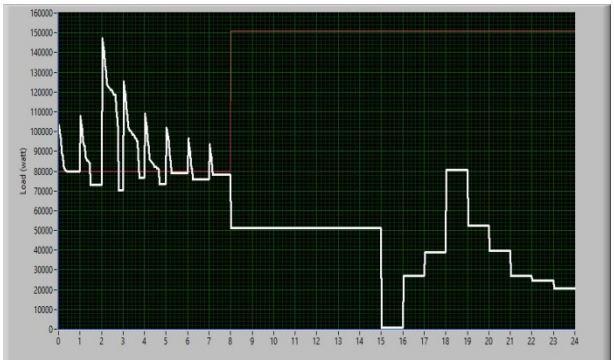

Fig.10. Industrial load after shifting

Energy Cost comparison can be summarized in the table below. Energy cost is taken as □: 3/ kwh for off peak period and □: 5/ kwh for peak period.

TABLE: 3

Status of the load	**Cost comparison of different types of load**			
	Residential Load	***Water pump load***	***Flour Mill load***	***Industrial Load***
Before DR	□: 285.03	□:187.03	□:108.3	□: 6269
After DR	□: 268.83	□: 161.67	□: 100.7	□: 5317

V. CONCLUSIONS

Using LabVIEW Load curve is prepared. By considering the DR limit, Time of use (TOU), priority of load, comfort level and flexibility, load is shifted to off peak period during DR event and hence peak shaving is done. Energy cost after load shifting is also calculated. Here load is not curtailed but it is shifted to off peak periods hence total energy consumption remains same. When we change the thermostat setting of controllable loads [7], by changing the thermostat setting, energy consumption can be reduced. Comparison of energy cost before and after shifting of load is as mentioned in the table 3. In this DR program consumers can interact with the system for changing the preference settings. This type of DR

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program is useful for deciding TOU tariff as it has taken into account consumers' behavior in response to change in price.

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