Demand Response Management in Smart Grid

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Abstract—Growing population and technological advancement are prime reasons for increase in the consumption of electric energy. Increasing need for power has become one of the pressing issue for every nation. Conventional electrical grids are unable to maintain balance between the demand and supply, which gave idea about transforming the one-way power supply to two-way communication between grid and consumer, make it smart and reliable by adding computational power to the grid. Due to increasing carbon emission, world is facing various hazardous environmental consequences like climate change and global warming, one of the solution for decarbonization is to generate electricity from the renewable sources of energy and efficient use of current power resources with minimum wastage. The demand response management system plays critical role in this initiative.

I. INTRODUCTION

Grid in distributed computing architecture is nothing but large number of independent computers connected to solve a complex problem. In the grid computing model, machines utilize the same resources collectively. The challenges in existing grids are, they cannot keep up with increasing demand of power supply and also it is hard to provide stable and sustainable electricity supply with existing grid structure. Also, with increasing concern for the environmental aspects (Global warming), grid should be more efficient, reliable, secure and greener, which can minimize the wastage of electrical energy and efficiently use the renewable and non-renewable energy resources. All these intricate challenges were driving force behind the evolution of smart grid technology [2].

Smart Grid which is intelligent or modern grid that uses new technologies to reduce the environmental impact of grid, increasing efficiency, energy conservation, renewable energy utilization. The majority of traditional electricity grids are not designed to comply with climate changes, latest ways of energy-efficiency nor use the latest technologies. With the incorporation of smart technology in the grid, we can create a system, which will exchange electricity and information between utility and its customers. There are myriad number of ways smart grid can be used in distribution intelligence, the department of energy of united states proposes 4 different types of forthcoming technological advances which will lead in the smart grid technology:

- Communication between electrical grid components:

Communication between components of grid is necessary in order to achieve automation an integration between the components, so that the system can react appropriately to given requirement based on the given state of grid. Load balancing can only be achieved if there is advance switch planning control for each grid component [3].

- Sensing and measurement technologies:

It helps in reducing the operational and management cost of grid components which in turn helps the consumers with lower power cost. Also, by sensing the peak hours of power consumption will help in maintaining balance between demand and supply. Loss minimization and load balancing can be achieved by analyzing the data measurements and plan for the worst case ahead of time, this can only be possible because we can measure and analyze current traits in the power requirement [1].

- Distribution and repairs:

By providing automated controls for distribution of electrical energy form stations to consumer and for repairs in the grid components, more efficient and reliable transmission of electricity can be achieved. For example, outage detection and various management activities related to it [3].

- Improved management and decision support software:

In case of power disturbances or failures, for quicker restoration of power, electrical grid has to detect the cause of failure and make a decision based on the data received. Managing demand response actions – Either by decreasing demand through reduced voltage on the distribution network or regulators can ask consumers to change their electricity consumption patterns when supply is short. We will further discuss demand response management in detail [7].

II. DEMAND RESPONSE MANAGEMENT

To understand the basic concept of demand and response system, we will use analogy of demand response system with weighing scale. Consider, demand is on one side of the scale and response is on other side. The task of given system is that to maintain weighing scale pointer constant. Federal Energy Regulatory Commission defines demand response (DR) as, changes in consumption (demand) of electricity by end consumers, in response to the prices of electricity over time. The prices inflates in response to higher demand for the power supply than regular and companies provides incentives in case of higher supply and very less usage[5][6].

As we already know, we are in the middle of the non-renewable energy resource crisis and we cannot afford any wastage of energy. Currently we have limited supply but day by day, demand is increasing due to advancements in technology. So, the conventional grid systems are not fit for the task, as in conventional energy supply, consumer's feedback is not taken into consideration, it is one way power supply. This leads to congestion in power supply, wastage of energy and unreliability and inconsistency in the electricity supply. Smart grid provide means for two way traffic between grid system and consumer, grid system takes consumption and performance data from consumer into consideration and based on the trend decides the peak values for power supply for specific periodic time intervals. Now, all of these data goes to the demand response system, whose sole purpose is to maintain demand supply balance. As, we have limited power supply, we have to put restrains on the demand of consumer. This can be achieved by many ways, one of the approach is to apply time based rates that means charging more amount at peak hours that the normal rate, so that the consumer should put limit to their usage. Another approach is to provide some rebate or incentive or lowering cost in bills, for limiting their power usage during peak time. Similarly, if the demand is very low, it can be balanced out by lowering cost on electricity for given time period to boost up the usage. Also, demand response system consists of sensors for sensing the excessive load on the station and based on the system decision, it can either deny the services or divert the load to most strategically located station.

As part of smart grid initiative, advanced metering infrastructure (AMI) systems are now incorporated with the demand response systems. According to this initiative, you can see the current usage and cost of electricity before generation of bill, just by logging to your on-line account or via your smart phones. As, more than half world is connected by Internet, it provides platform for engaging the consumers responses in the real time demand response events. Due to demand response system, both the parties (supplier and consumer) are being benefited and it helps in maintaining power supply efficient and reliable on both ends [5][6].

III. IMPLEMENTATION

We have implemented demand response management with distribution intelligence. Our implementation requires peak values of power requirement on biweekly basis from all connected households and companies per station, which consists of hourly based peak consumption values. We then analyze the trend from this historical data for peak values. We calculate average peak values per hour for all households or industries included. The information that we collect is in the following format.

TABLE I

U_ID	ST_ID	DATE	DAY	SLOT	AVG	PEAK
12021	101	4/3/16	Sunday	1	418	448
12022	102	4/3/16	Saturday	2	438	468
12021	101	4/3/16	Monday	3	186	216
12024	103	4/3/16	Tuesday	4	356	386
12023	104	4/3/16	Sunday	5	228	258
12025	105	4/3/16	Tuesday	6	396	426

a. Power consumption data format per household per hour

These input files are collected per station and new average peak values are set per day per hour for respective stations.

e.g. for Station 101, we have set following average peak values

Saturday, 9:377

Wednesday, 24:372

Friday, 20:385

Wednesday, 3:413

Friday, 24:314

Whenever consumer requests power supply from the power station, it redirects the request to the demand response system, where the system makes decision based on the peak value for given location at given hour. If the value is within the threshold limit, then system gives green signal to the grid to send the requested amount of electrical energy, else if the value exceeds the peak limit, then the system serves the request with a warning message to the consumer for exceeding the threshold limit at given time (exceeding consumption can be charged more, for each unit of electricity after a particular limit). If the current usage reaches the threshold value of any particular station, the station then borrows energy from other stations.

In following figure 1, Station B has reached its threshold value. It then calculates how much power it is expecting in next 2 hours based on average peak values set from historical data. The required unit request is then broadcasted to all connected stations. If current station has previously lent some units to other stations then at first those stations are preferred. There are two types of requests to implement this efficiently.

Types of requests:

1. Withdraw Request – Current station broadcasts this type pf request in case it had previously lent some power to other stations. This request is sent to these stations only.
2. General request – Current stations broadcasts this to all other stations in case withdraw request didn't get any response.

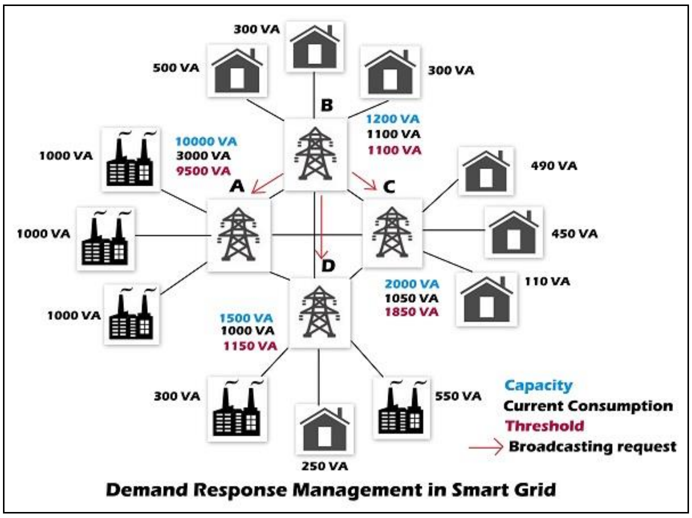

Fig. 1. Station B broacasting general power request

Whoever, sends the positive reply to general broadcasted request that station thus lends required power units. New values of capacity and threshold are updated in both the systems as shown in figure 2 i.e. the station which requests and station which lends the power units.

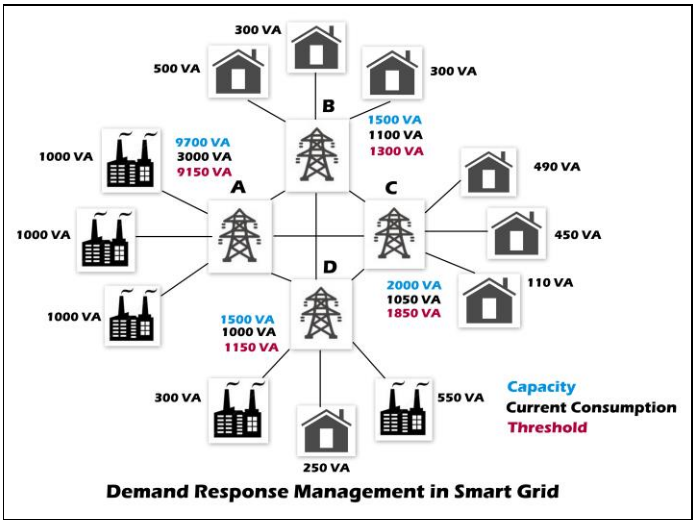

Fig. 2. New capacity and threshold values after balancing

As we have peak value data on biweekly basis, at the end of 2nd week we need to update peak value table, with new peak values observed on the basis of current trend in the demand for power supply and this updated table goes input to demand response system for next cycle.

IV. RESULTS AND CONCLUSION

After running the above implementation for few iterations, we can see the alleviation in the demand of power supply at peak hours, as we are sending warning/response to consumers (analogy to price increment). The utilization of energy at peak hours has decreased by 10-15 percentage. This helps in increasing end users' awareness towards a more rational use of energy.

Analysis of usage patterns by households or industries plays a key role in distributing required resources by considering the request patterns of all sub-stations. This includes capacity, threshold value of the each sub-station. Also as these values are revised after fixed interval of time (in or implementation, it is 2 weeks), the solution adapts itself to the current need.

Implementing the similar intelligence with smart meters can help us leverage the job of smart grid to smart meters. Smart meters can then manage power for household machines or devices like AC, heater, fridge, electric vehicles efficiently. This also help users to analyze, forecast or regulate their own energy consumption pattern [6].

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