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Load Confinement for Implementation of Load Management on Consumer Side using Smart Grids

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***Abstract*—** Earth is facing the issues of power crises despite of the fact that it contains unlimited resources in it. This is all due to mismanagement of resource usage or poor planning. Exploring and developing of new ventures takes time and budget, so for developing and under develop countries it is very tough to manage, so all they are left with is well management of resources. Problem the world, especially South Asian countries are facing with conventional load management is the loose control on consumer demand, peak shaving methods, efficient utilization of system and poor reliability. This paper is proposing an idea through which we can manage high power demand of consumers, utilize the power generated efficiently and promptly, take control of load on very root level, increase or decrease it, instead of cutting of whole feeders for peak shaving called as Load Confinement Method. The process is implemented using simulations, performing several experiments.

***Keywords*—** Load Management (LM), Load Shedding (LS), Demand Side Energy Management (DSEM), Renewable Energy (RE), Solar Energy, Nuclear Energy, Wind Energy, Smart Grids (SG), Smart Meters (SM), Load Confinement (LC).

I. INTRODUCTION

For stability of grid operation, electricity supply must be equal to demand [1]. Major imbalance in supply and demand causes frequency fluctutaions, generation failure and blackouts [2]. In developed countries, the blackouts are avoided with contigency plans for continuity of supply. This plan consist of multiple levels on small and large scales [3]. In developing countries, the situation is opposite, as its very difficult to make any long term plan with insufficient power system data, demand and supply curves are always random, non predictive and extremely complicated to handle for grid operator [4].

In this time of modernization, still over a billion people don't have electricity [5]. Alone in India, there are 239 Million people without electricity and Pakistan and Bangladesh has over 25% of population without electricity [5]. The reliability of supply can be increased only by decreasing the system voltage,hence decreasing the overall load. These blackouts and supply cuts are seen as the source of cutting load and balancing the demand and supply electricity to every area for some time [4]. Sales of electricity in Pakistan have increased from 17.6TWh in 1985 to 100TWh in 2017 which is six times increase in sales [6].

These mismatch of demand and supply creates outages and electricity outages creates huge losses to economy of countries [7]. So small household tends to adopt some back system in the form of diesel generator or unintrupted power supply (UPS) [8]. In both choices of backup supply UPS gets an upper hand on generator due it small size, low noise, easy handling, low cost etc but its overall impact on system is still hidden, as the efficiency of domestic UPS system are quite [4] These UPS comprises mainly on Lead acid batteries as storage device [8] which on its own is very un-efficient. It is well documented by [8] that combine efficiency of charging, discharging and UPS circuitry drops well below 50% which shows a huge loss of energy and extra burden on system.

Discussing about energy conservation with better quality battery storage backup supply and desmand side management by usage of smart devices in coordination to smart meters will help us in load forecasting and load management [4]. Elaborating the load management, the paper emphasis on direct control of load from control center reducing the demand with usage of smart devices instead of classical equipments [4]. Showing the impact of battery dependent backup system, [4] perform an experiment that a transformer of 25KVA feeding a domestic area consisting of 15 houses, was rarely overloaded, but one third of same houses when installed with battery supported back up system, the same transformer was overloaded up to 170% of its capacity during summer season.

Billions of dollars of developing as well as developed countries are lost annually due to power outages and load management [9]. Strong power system infrastructure is the emphasis since last decade. Quality of power supply is decreased as the usage of electricity is increased [9]. In 1985, total energy generation of world was 10 PWH where as it improved to 20PWH in 2011 showing the increase is on double after lapse of 25 years, but on the other hand the energy demand is rising more than the production [10]. As the definition goes, load management is the procedure by which the supplier balances the demand of energy with the production of energy and keeps the rated frequency between its acceptable levels. This procedure enables the energy supplier to meet the demand

in peak time economically [11]. Smart Grid (SG) is a thing of future which proposes different intelligent methods to solve this energy shortfall issue [10].

As a part of developing country, we hugely face the issue of Load Shedding/Management exceeding several hours per day. This load management is result of cutting off low recovery area in time of peak demand [12]. This is the method used conventionally as it has several advantages of its ease of implementation; economy and no infrastructure are needed. However, these direct cutting areas out of power supply impact hugely the repute and reliability of supplier [13].

This paper furthers the work of [14] regarding direct load management using smart meters and minimizing the use of battery storage back up supplies by proposing a method which is increases system reliability and efficiency by eliminating outages completely, minimizing the need of Backup supplies [15]. It is proposed that during high demand time, instead of cutting the low recovery areas, perform DSM by limiting each consumer to its Base/Backup load only by switching the smart devices [16], thus reducing/shaping the overall demand during peak hours and also saving the consumers from complete power failure, hence improving the consumer reliance on system and well as reliability [17].

II. LOAD CONFINEMENT TECHNIQUE

This method suggests that the load of each and every consumer will be limited instead of complete outage, during peak hour, by using smart devices. For purpose of understanding, consider the load limits reduced to the same load which the backup supplies were going to provide during load management hours. By this way every consumer will be controlled directly by intelligent servers in control center with the help of smart meters.

Figure 1. Smart Meter

This different type of load is divided into different classes depending upon their nature and named as "Consumer Classes" as given in Table 1. Every consumer class has well calculated "Back-up load" limits which in case of usage of smart devices will be implemented automatically and in case of conventional devices, signal will be given regarding system to consumers which each consumer has to follow during peak hours. If the consumer violates the set limits by the supplier, the energy meter has the capability to sense, warn through SMS/messaging and then cut the connection till the end of peak hour. Also system data and set limits are shared time to time with consumer to keep them well informed. This technique will make sure that every consumer gets a fraction of power generated during peak hours instead of complete power cuts.

As it's a common practice that whenever there is supply cut, all consumer have their back-up supply, first of all they turn off all the equipment of household/industry, then they shift slowly and gradually to back-up power supply, reducing their overall load and tends to maintain that load until the supply is restored from main power supplier. This is how a whole area which was running on routine load, abruptly switches to reduced/back-up load during supply cut. This paper follows the same concept but suggest that the back-up load which the consumers are getting from backup supply now should be fed by power supplier, called as "Back-up Supply". The time/duration of peak hours and back up supply limit should be communicated to consumer prior to the peak hours, so every consumer manages/reduces his load. If any consumer violates/ignores the intimation by system of reducing load, then should be cut off completely for pre-decided time span or until the peak hours finishes, the option is left to the consumer. Consumer classes have been set for distinguishing different type of consumers and their set load limits during peak hours. The back-up load limits is worked through the following equation.

Total Generation Capacity (TC) = C1+C2+C3+C4...+Cn.

$$Cn = TC * Pn$$

Where, $P1+P2+P3\ldots..+Pn = 1$

Also, $$Cn = Nn * V * BL$$

$$BL = Cn / (N * V)$$

So,

Pn = Priority for Consumer Class
Cn = Power Allocation for Consumer Class n
Nn = No of Sub Consumers of Consumer Class n
V = Voltage Supplied
BL = Back-up Load

For Example, for generation capacity of 1000MW, following are the back-up load limits.

Table 1: Consumer load Classes and Back up Load

S #	Consumer Class	Priority (Pn)	No of Sub-Consumers of Consumer class n (Nn)	Voltage Supplied	Back-up Load (BL)
1	Domestic	0.2	100k	220V	9.09A
2	Commercial	0.24	200k	220V	4.95A
3	Industrial	0.26	100	440V	5909A
4	Medical	0.2	200	440V	2272A
5	Government	0.1	1k	440V	227A
	Total:	**1**			

An area fed through feeder have multiple of each consumer class. With the help of smart meter, the above loads limits will be conveyed and implemented on each consumer. The smart meter have the ability to SMS, communicate with smart devices/consumer/supplier, sensing load and cut off/restore power connection. To analyze the usefulness of this technique, it is implemented through software and the results are analyzed.

III. SIMULATION AND TEST CASES

This technique was implemented in MATLAB Simulink and response of the system was noted that how it impacts over all loading curves.

Three different types of simulation tests were performed and their results were analyzed and compared with conventional load management. The source used in the calculation/simulation is 200KVA transformer.

Test Case 1

Fig. 2 shows collective load of 15 consumers and the transformer can be seen almost 90-100% loaded before load management. After implementation of load confinement technique the load is reduced by 50%. It means 40 % load is reduced from conventional system and no supply failure is faced by the consumer during peak hour.

Test Case 2

In second experiment the consumers are increased to 30 and same scheme is implemented. First when the routine load is fed, the transformer got overloaded by 180%. Then back up limit is set to each consumer and the overall load on transformer is reduced to 40% as shown in fig. 3.

Test Case 3

In third experiment fig.4 shows that the transformer rating is improved and different nature of consumers are considered with different loads. The overall load limits was set on 1000A on transformer to keep it from overloading. Initially the overall load was within set limit, so no action is taken by smart meter and same load was being fed. But when the load crosses the 1000A limit, the smart meter start shaving the peak and 15-20% load confinement is performed to keep the system within levels.

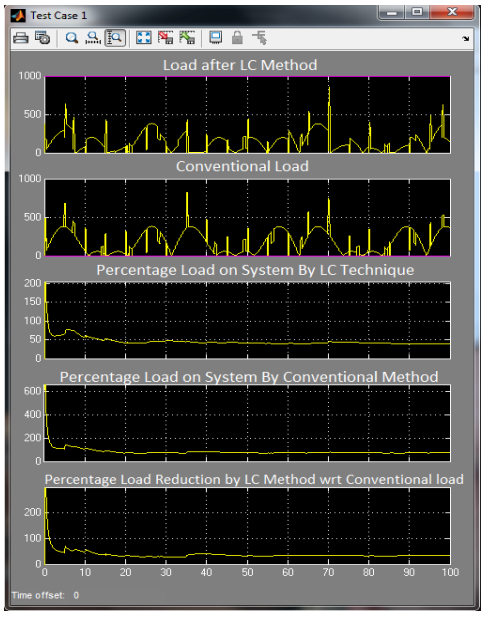

Fig 2. Experiment 1 Results

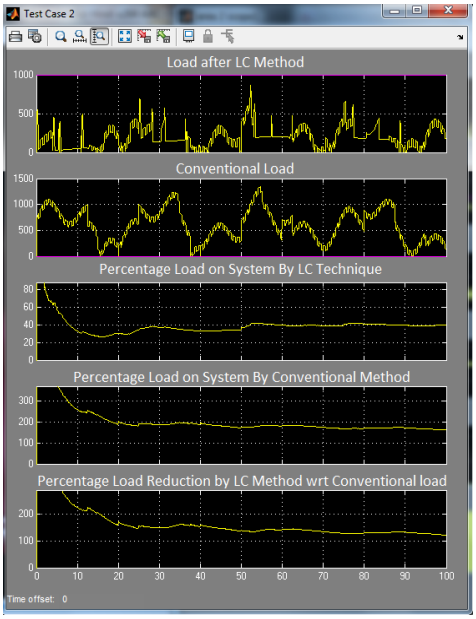

Fig 3. Experiment 2 Results

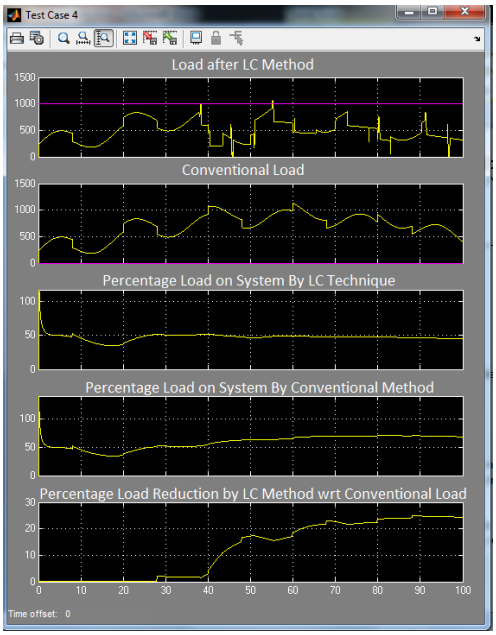

Fig 4. Experiment 3 Results

This experiment shows an interesting sequence that both the waveform before and after application of LC technique, are the same until the load exceeds the set backup limit.

IV. RESULTS AND COMPARISON

The results show that the load confinement technique reduces the overall load as per set backup limits and provide useful results.

- The results show that the conventional load curves were shaved/reduces after implementation of LC technique as shown in fig.5.

- This technique limits every consumer to backup load hence making the overall system very predictable and manageable. It provide ease to system operator to manage load easily and the cases of abrupt increase in load will decrease.
- In case of limit violation the connection is terminated by smart meter. The smart meter act as an intelligent switch, deciding and disconnecting in time.
- All experiments were successful in reducing overall load on system. The load is reduced
- It's a complete scheme addressing many issues of conventional LM technique. It can be implemented easily with installation of only smart meter and upgraded control centers. Also if user uses smart appliances than switching will be more user friendly in comparison to conventional passive loads.
- Smart meter can be programmed to manage load during peak hours on its own but if conventional loads are used then the consumer has to manually lessen the load during peak hour.

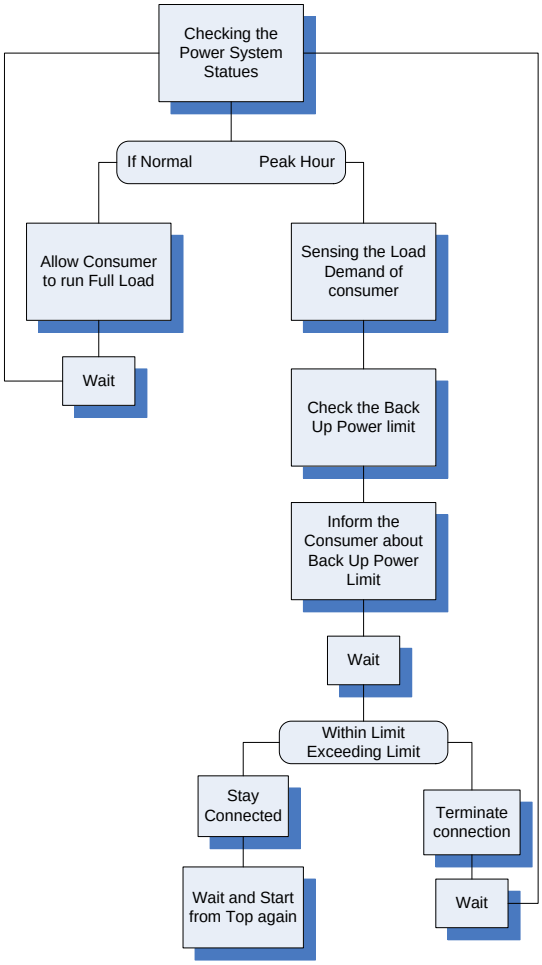

Fig 5. Step wise Flow Chart of Load Confinement Technique

V. FUTURE WORK

SG is only implemented on very basic level in even developed countries and a lot of work can be done to improve. The lot of future work can be performed on LC technique for betterment too, such as:

- Work can be done on improving data communication between consumer, control center and smart meter such that consumer manages their load remotely and plan a schedule to control their bills.
- Work can be done for studying the impact of transients made during switching of devices during peak hours.
- If the connection is cut off due to voltage violation then there should be an option through which a consumer can request for restoration of connection once he brought his load within limits.
- During peak hours if consumer requires full/normal load, then he can request control center but with higher tariff.
- As most of the consumer are using simple devices (with no smart option), the manual switching of equipment for consumer is hectic. So, further work can be done on design of control box which enables smart meter to switch all devices as required spontaneously.
- Work can be done on intelligent algorithm for setting back up load limits in real time. All experiments were performed with random values for analysis purpose only. In real time, the system will decide load limits and change it with requirement of system and feed it to each consumer.
- Mentioned advancement in the technology requires work complex networking and communication, which increases the overall cost of the system. It's always a trade-off between cost and technology. So we always choose the features which we require supremely at first.

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