LOAD FACTOR BASED TARIFF

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ABSTRACT

The peak load of electricity power is created by customer's simultaneously consumption and creates the power shortage in definite times. This difficult is one of the most important problems of electricity utilities that can be solved by DSM before than increasing of electricity network capacities' and better than increasing of electricity power and energy generation with preserving of environment and energy recourses.
The electricity tariffs play a key role in DSM. The electricity utilities for this purpose by installing multi rate meters often use a tariff structure that relates the rate of energy to it's time of use (TOU) for encouraging their customers to load management.
But in spite of using this tariff structure the power shortage problem in peak times often has remained unresolved and maximum power demand is growing gradually while the utility's load factor is falling continually. This failure in DSM strategy basically returns to the technical disadvantages of TOU tariff structure as a fault tactic, and then this paper recommend substituting a new and better tariff structure instead of the existing TOU tariff.

INTRODUCTION

In sometimes of a day or a week, because of customers' simultaneously consumption the demand of power electricity is in the peak and overloads the capacities of electricity network for generation and distribution. This is an important problem and danger appearance that must be solved in any way, because it threats the quantity and quality and reliability of electricity utility's services as the safety and existence of network's and customers' electrical equipments in any moment, and then what is the solution?

SOLUTIONS FOR PEAK LOAD PROBLEM

The electricity utilities that suffer from power shortage in peak periods; have three solutions for keeping the reliability of electricity network and avoiding any damages to the network's equipments against overload current and keeping the consumers' instruments against voltage drop:

1- To switch off the overloaded feeders and transformers and interruption the power of customers by help of dispatching unit as an emergency and temporary solution and the last selection for resolving the problem of power shortage in the peak periods. It is a harmful solution for both of electricity suppliers and consumers. This short-term solution is based on keeping the balance between existing demand and existing capacity without any long-term changes in them.

2- To increase the capacities of electricity network for generation and transmission and distribution according to the peak demand, that needs additional capital investment. Since the peak load isn't permanent and is used in short periods everyday so it can't return the capital gain of electricity utilities' investment with the usual rates, unless the rate of energy in peak period be higher than the other periods for compensating the loss of unused capacities in off- peak period for encouraging the utilities toward more investment. This solution is based on more investment for keeping the capacity greater than the existing demand.

3- To encourage the consumers by discounted rates based on time of use (TOU) tariff for demand side management (DSM) and demand side investment. TOU tariff divide the times of a day to peak and partial peak and off- peak hours according to the load profile of a utility. While the peak rate is higher than partial peak and off-peak is the cheapest rate as the customers can save charges in their billing by load management. This solution is based on keeping the demand less than the existing capacity by DSM and encouraging the customers to act as voluntary dispatchers of demand side.

TOU tariff as a tactic for DSM

The two last solutions for peak load problem mentioned above are based on TOU tariff. The electricity utility for keeping the balance between capacity and demand without power interruption need to TOU tariff, either decided to add its capacities of generation and distribution up to existing peak demand by additional investment or decided to reduce the peak demand down to it's existing capacities by DSM.
In each case the TOU tariff must be used by electricity utilities for customers' billing. The consumers by DSM and performing of load management programs as peak shedding and load shifting and valley filling, can save charges in their billing by use of discounted rates based on TOU tariff. While the benefit of electricity utilities by DSM come from cost saving because of avoided capital investment for installing additional capacity of electricity generation and distribution.
As the load management and peak shaving has common benefits for both sides, so its profits must be shared between them equally. The electricity utility's benefits from higher rate of peak tariff and the customer benefits from discounted rate of off-peak tariff.
The higher rate of peak tariff encourage the suppliers to increasing the capacity of electricity network for generation

and distribution up to peak demand while the discounted rate of off-peak tariff encourage the consumers to decreasing their electricity demand in peak hours for charge saving.

This paradoxical role of TOU tariff drive both sides to an optimize situation. By fixed TOU rates and hours there is an optimize point for peak demand of load profile. By any change in them, the optimize point of peak demand must move to a new situation. When the peak rate or peak hours arise then the demand must fall down. If this relation isn't true, then the TOU tariff structure including the rates and the times are mistaken and must be corrected.

The discounted rate must be proportional to the supplier's saving cost for avoided capacity and to the customer's costs for demand side management & investment for load management and peak shedding.

The difference between the peak and off-peak rates must be encouraging for both sides and the average of them must be equivalent to the partial peak rate and proportional to the sum of prime cost and profit.

The peak& off-peak hours according to the adjustment of meters' tariff o'clock of a utility must be matched with the load profile of that utility and there must be no difference and time interval between them. The existence of a time interval between the TOU of meters' tariff o'clock and the TOU of utility's load profile, disable the TOU tariff for DSM, because the peak tariff would be applied to the customers when the load profile of utility isn't at the peak time.

Then any factor that produces a time interval between the adjusted times of meters' tariff o'clock and the real time of load profile, can be considered as a fault or an error and disadvantage of TOU tariff.

Disadvantages of TOU tariff:

Three factors can cause a time interval between meters' tariff o'clock and utilities load profile about TOU periods, which are considered as the technical disadvantages of TOU tariff:

1-Because of turning the earth around the sun, the seasons are happened and the length of day and night is varying and the times of sunrise and sunset are dynamic and moving and changing from one day to another continually.

The load profile of luminance consumption and then the TOU of residential consumers, approximately follow the natural times of sunrise and sunset, while the meters' tariff o'clock are adjusted for constant hours independent from changing of customers' TOU and their load profile.

Although the meters' tariff o'clock can be scheduled to change automatically by daylight saving mode or by tariff switch table programming, but the changes of meters' tariff o'clock are discrete and step by step, while the changes of natural times are allied and linear.

Hence there will appear a difference and a time interval between the times of peak& off- peak periods according to the adjusted times of meters' tariff o'clock and the real time of utility's load profile.

2-The other factor for existence of a time interval between the TOU period of meters and the TOU period of load profile return to exiting the meters' tariff o'clock from adjustment due to expiring the date of internal battery in digital meters or opening the circuit of electrical tariff switch o'clock in the mechanical meters.

3-The third factor for existence the difference between TOU period in meters and load profile returns to those utilities that their load profiles have two peaks time period in morning and evening ,while the TOU tariff according to the meters' tariff switch o'clock setting is defined only for one peak time.

The electricity distributions utilities at big towns often have this form of load profile (see fig. 1).The first peak of load profile occur at time interval of (11-15) and the second at (19 -23) and two peaks approximately have same height. The first peak often belongs to the official and commercial customers and the second peak belongs to the residential and business customers.

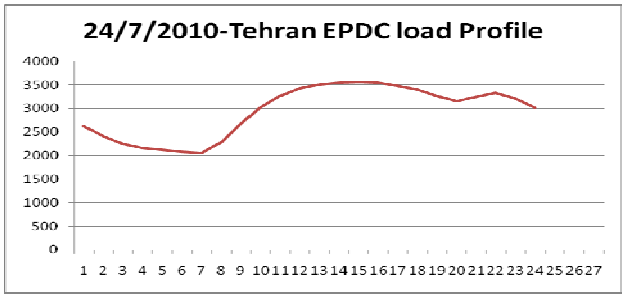

Fig.1: Tehran Great EPCD load profile with two peak load

If the peak period of TOU tariff is defined for the first peak of load profile (11-15) then some categories of customers as commercial sector have the chance of shifting some of their loads from first peak to second peak and saving charges in their billing by discounted rates.

In the other hand if the peak period of TOU tariff is defined for the second peak of load profile (19-23) then another categories of customers as residential, has the chance of shifting some of their loads from second peak to first peak by DSM and saving charges in their billing.

When the load profile has two peaks with the same height and the TOU tariff include only one peak period then TOU tariff and DSM and load management programs has no benefit for electricity utilities, because load shifting from one peak to another has no result for peak shaving.

In this situation although TOU tariff due to DSM but don't improve the load profile and load factor of utility and has no cost saving for electricity utility.

This problem can be solved by extension of TOU period to include both peak periods of (11-15) and (19- 23) as the peak periods of TOU tariff.

If the short valley time between the two peaks periods at (15-19) be ignored then two peak periods can be unified in one peak period of (11- 23), so the partial peak period is neglected and two- part rate (peak &off-peak) tariff is substituted instead of three- part rate (peak &off-Peak & partial peak) tariff .

Some utilities as Electricity Generating Authority of

Thailand (EGAT) have applied this solution and have reduced its demand by shifting the whole of the load profile to the down without shifting only the peak load and without improving its load factor. [1]
Although increasing the peak period from 4 hours to 8 or 12 hours by substituting the two peak periods instead of one peak period or by replacing the two-part rate instead of three-part rate tariff can resolve the problem of electricity utilities with two peaks of load profile, but by this way the load pattern and the work time of some customers is extended to another and the costumers rights are ignored.

LOAD FACTOR &LOAD PROFILE

There must be a factor for measuring the amount of progress and success of TOU tariff and DSM programs for reduction of peak demand or peak shaving and improvement of load profile. This factor is named as load factor (LF) and is defined as the ratio of average power to maximum power (demand) or the ratio of really energy consumption to the expected energy consumption by maximum power in a fixed period.
In other word the load factor is the ratio of average capacity used in all moments of a period to the maximum capacity occupied in one moment (measured in 15 minutes time interval) by customer within that period. The minimum and maximum amount of load factor is located between 0&1:
$0 \leq LF \leq 1$
LF = average power / maximum power (demand)
LF = consumed energy/ (t× demand)
According to the load factor definition when the average power become equal to maximum power (demand) then the load factor amount becomes equal to 1and it means that the load profile is a straight line parallel to the time axis.
When the load factor amount become far from 1 and near to 0 then the load profile shape become far from a straight line and near to a curve with height peaks and deep valleys next together.
Owning a load profile with a straight line form and a load factor equal to 1 is an ideal situation for utilities where all of customers consume the electricity energy with a constant power less than the existence capacity of power generation and distribution but it is an ideal situation not existing in the real.
In the real the customers consume the electricity with different and variable power but they can be encouraged by discounted rates based on TOU tariff to DSM and hereby the utilities can become nearer to the ideal situation but never they can reach it.

WHY LOAD FACTOR BASED TARIFF?

According to the quantity of utilities' load factor, the success of TOU tariff structure and the progress of DSM programs can be measured and evaluated.
In spite of widespread usage of digital multi rate meters and applying TOU tariff and performing of various DSM programs by electricity utilities and by their customers, the peak demand is growing increasingly in many utilities while the load factor amount often is about 0.5. Then more capital must be invested for increasing the capacity of power generation and distribution and more fuel must be burned in power plant for energy generation and more carbon dioxide must be produced and the natural environment must be polluted more and more.
These facts besides the faults and disadvantages of TOU tariff must encourage the electricity utilities for innovation of a new tariff structure instead of existing TOU tariff that respect to the consumers' rights and encourage them for participation in DSM activities.
The most important tactic for DSM strategy based on TOU tariff is load shifting from peak to off- peak period. But performing of this tactic is possible only for some customers and is impossible for many of them.
The industrial customers and factories for example by construction of third work shift in the night can shift part of their power consumption from peak to off-peak period, also some residential customers, hotels and hospitals can shift part of their consumption as washing machine and iron from evening to morning or to night. But the official and commercial customers and business sector can't do it.
They can't change their jobs or their work time and shift their works to second or third shift or turn- off their heaters and chillers at on-time and turn- on them at their off- time. Therefore some customers can participate at DSM and use discounted rates while many others can't do it in spite of their willing.
The TOU tariff with imposing a definite time of consumption and unjust distribution of time between consumers, indeed want to impose a definite load pattern and behind it want to encourage a definite and imposed model of life& work to various categories of customers regardless of their natural differences in jobs & work time, so it isn't wonderful that TOU tactic can't encourage the customers to DSM strategy.
The TOU tariff ignores the freedom of customers for selection the time of consumption and by discrimination between the times of use, discriminates between the users and customers.
Each category of consumers depends on their nature, job, work-time and other specifications have an especial load profile and peak& off-peak period, different from the other customers and from the utility. But TOU tariff with ignoring these differences want to unify the load pattern of all customers.

Constant rate for constant power

The electricity utilities from economical and technical consideration have the right of owning a network with constant power of generation and consumption and a load factor near to 1 and a load profile as a straight line with no height peaks and deep valleys on it, until no capacity remain unused and any capital investment become without profit.
But for achieving to this ideal network, the utilities can't forget the rights of customers for free selection the time of use with any difference between the times of day.

The utilities must encourage their customers to consume the energy with a constant power by a constant rate in all times. This origins and fundamentals in my opinion prove the necessity of changing the existing tariff structure and substituting the load factor based tariff instead of TOU tariff.

In the new tariff structure based on load factor there is no difference between the times of use or the times of day and the electricity energy is sold by one rate in all times, as the customers have the right of consumption in every time with one rate and the utility has no right for applying additional charge or penalty to the customers' bill if they have consumed the energy with a constant power.

But when the power consumption is varying through the time, then a penalty must be added to the electricity charge proportional to the load factor quantity.

The load factor penalty encourages the customers for improving their load profile & load factor. If the load factor quantity be equal to 1 as the ideal load factor, so no power factor penalty will be added to the electricity charge and then the customer will have charge saving. Then the utility's load factor & load profile is improved by improving the load factor & load profile of all customers.

Load factor based tariff equation

The equation of load factor based tariff and load factor penalty can be resulted as the formulation of reactive charge or power factor penalty. [1]

Like as the energy charge was calculated proportional with the ratio of active energy to power factor, here the electricity charge according to the load factor based tariff is computed proportional with the ratio of active energy to load factor:

If: LF=1→

Electricity charge (without load factor penalty) (¢) =

= [rate (¢/kWh) ×active energy (kWh)] /1 =A

If: LF<1 →

Electricity charge (with load factor penalty) (¢) =

= [rate (¢/kWh) ×active energy (kWh)] /LF =A / LF

Load factor penalty (LF penalty) = - charge saving =

=electricity charge (LF<1) - electricity charge (LF=1) =

= [A/LF] – A = A [(1/LF) – 1] =A× loss factor

Where: loss factor = (1/LF)-1

If: LF=1 → loss factor=0

If: LF<1 → 0< loss factor<1

Like as the incentive power factor for reactive penalty, an incentive load factor can be defined by utility to encourage the customers for load factor improvement and charge saving in their electricity billing.

When the customers' load factor becomes equal or greater than the incentive load factor, then the customers' load factor penalty is zero.

The amount of incentive load factor depends on the existence load factor and the ideal load factor that a utility has scheduled to reach it. The suggested incentive load factor here is 0.75.

By substituting the amount of incentive LF in the above equation, the last relation for load factor based tariff is resulted as follow:

Electricity charge=A× (incentive LF) /LF

If: LF≥ (incentive LF) →electricity charge=A

If: LF< (incentive LF) →electricity charge >A

LF penalty= ([(incentive LF)/ LF]-1) ×A = loss factor ×A

Loss factor= [(incentive LF)/ LF]-1

LOAD FACTOR TARIFF&DEMAND TARIFF

Almost all of electricity utilities see the TOU tariff as the unique tactic for DSM and load management, ignoring the other existence tactics. The demand tariff can be used as the best tactic for DSM strategy and peak shaving, if the demand charge be computed based on customers' peak demand instead of contracted demand.

The demand tariff based on contracted demand is a constant charge in electricity billing, regardless of customers' peak demand, so there is no factor encourages the customers to DSM because the demand charge based on contracted demand is independent from maximum power consumption.

By computing the demand tariff based on customers' peak demand instead of contracted demand, it is resulted that if the customers' peak demand be less than of contracted demand so the consumer must have charge saving as an encouraging factor for DSM same as, if the customers' peak demand be greater than contracted demand, then he must pay penalty.

As the electricity tariff based on load factor is the ratio of consumed energy to LF, where LF is the ratio of average demand to maximum demand, then the LF based tariff is proportional to customers' peak demand and this new tariff structure include the demand tariff based on maximum demand.

Therefore the demand tariff and load factor based tariff are united in one tariff and can act as the best tactic for DSM strategy and do the best role for peak shaving and demand control.

CONCLUSION

The load factor based tariff is a better tariff structure than TOU tariff and a better tactic for DSM strategy, as it distributes all times of a day between all customers equally with no difference between the times of use and encourage the customers to increase their load factor by reduction of simultaneously consumption.

REFERENCES

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