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Research Paper

MICROCONTROLLER BASED MAXIMUM DEMAND INDICATOR AND CONTROLLER FOR EFFICIENT POWER MANAGEMENT

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Power is measured in instantaneous quantities, while energy is the integral of power over time. For example, a 100 W light bulb absorbs 100 W of power. If operated for one hour, that light bulb absorbs 100 W – hours of energy. Maximum demand is the maximum instantaneous power consumed over a specified window of time. In the case of that 100 W bulb, as it is switched on and off, the instantaneous demand goes from zero to 100 W to zero, etc. Not very interesting. But if that bulb is operated in parallel with a second 100 W light bulb that is left on all the time, the demand will switch instantaneously between 100 W and 200 W, and the maximum demand of the combination will be 200 W. Now, the way this is applied is that electric distribution utilities often include demand as one of the factors used to determine the bill the consumer receives. In addition to measuring integrated energy consumption over the billing period (typically a month), they also measure demand. Rather than measure truly instantaneous values, they actually measure energy over a short window of time, and then divide the energy consumed during that interval by the length of the interval to arrive at an effective peak value for the interval. This is done because truly instantaneous measurements can be distorted by common events such as starting a motor (El-Sayed, 1999). So, for example it is fairly common to see demand referred to as 'fifteen minute demand' because it is the effective peak value over a fifteen minute window of time. The reason for measuring and charging for demand is that the distribution utility has to build out its infrastructure to be able to support the peak consumption by its customers. Measuring and billing for maximum demand is a way of assessing the degree to which the needs of individual customers are driving the expansion of the infrastructure that supports all customers (Mostafa *et al.*, 2004).

Keywords: MDI, Power factor, Penalty, Load management

INTRODUCTION

The greatest average value of the power, apparent power, or current consumed by a customer of an electric power system, the averages being taken over successive time periods, usually 15 or 30 minutes in length.

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It is the greatest demand of load on the power station during a given period, i.e., the maximum of all the demands that have occurred during a given period (may be a day, may be an hour, etc.).

Need of maximum demand in Electricity bill?

When the rate of electrical energy is charged on the basis of maximum demand of the consumer and the units consumed, it is called two-part tariff.

In this total charge is divided into two.

1. Fixed charge depends on maximum demand of consumer.
2. Running charge depends on no. of units consumed. It is measuring by installing maximum demand meter. Charges are made on the basis of maximum demand in KVA and not in kW.

The maximum demand is further split into four types, namely:

1. Daily maximum (0530 h to 1630 h and 1830 h to 2100 h).
2. Restricted maximum (1630 h to 1830 h).
3. Night maximum (2100 h to 0500 h).
4. Weekend maximum (Saturday 0500 h to Monday 0500 h).

Each type of maximum demand has a different tariff. Maximum demand is usually measured as an average over a half hour period. The maximum half hour average reached during the month gives the monthly maximum demand charge (Gaggioli, 1983; and Clive Beggs, 2002).

It is important to note that while maximum demand is recorded, it is not the instantaneous demand drawn, as is often misunderstood, but the time integrated demand over the predefined recording cycle.

As example, in an industry, if the drawl over a recording cycle of 30 minutes is:

2500 KVA for 4 minutes

3600 KVA for 12 minutes

4100 KVA for 6 minutes

3800 KVA for 8 minutes

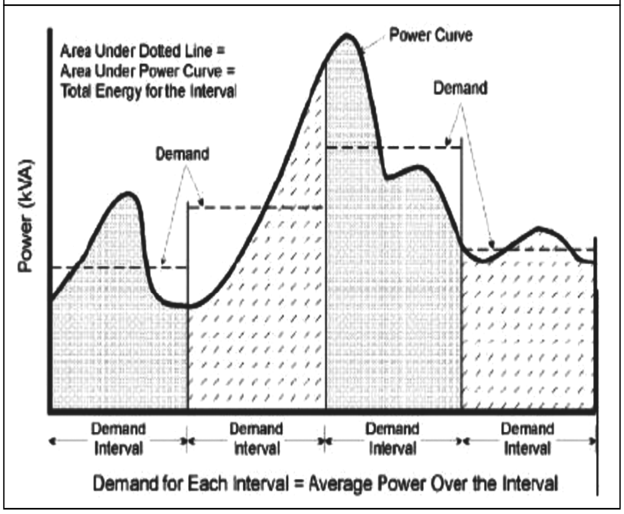
The MD recorder will be computing MD as:

$$\frac{2500 * 4 + 3600 * 12 + 4100 * 6 + (3800 * 8)}{30}$$

= 3606.7 KVA

As can be seen from the Figure 1 below, the demand varies from time to time. The demand is measured over predetermined time interval and averaged out for that interval as shown by the horizontal dotted line.

Figure 1: Power and Demand Curve



MDI PENALTY

The MDI penalty can be avoided by improving the power factor and by using more efficient appliances.

Another option of avoiding MDI penalty is by shifting your peak load to a time of day when your load is less.

There are 2 methods of calculating MD (Maximum Demand):

NORMAL OR BLOCK METHOD

At the end of each fix integrating period, average power for that period is calculated. If this value is greater than already existing value then this is stored as the MD.

SLIDING WINDOW METHOD

At the end of a sub integrating period the avg power is calculated for one integrating period. If this value is greater than the already existing value than this is stored as MD. The integrating period slides by a window of the sub integrating period (Capasso *et al.*, 1994; and World Bank, 2012).

MD No.	Method	Intg. Period	Sub Intg. Period
MD 1	Sliding	30 min	15 min
MD 2	Block	30 min	30 min

Assume a load pattern of following type:

$T = 09.00$, $T = 09.15$, $T = 09.30$, $T = 09.45$, $T = 10.00$

20 KVA, 30 KVA, 30 KVA, 20 KVA

15 mins, 15 mins, 15 mins, 15 mins

For MD 1 (Sliding window method)

Demand – 09.00 to 09.30 block

$$= \frac{(20*15+30*15)}{30} = 25 \text{ KVA}$$

Demand – 09.15 to 09.45 block

$$= \frac{(30*15+30*15)}{30} = 30 \text{ KVA}$$

Demand – 09.30 to 10.00 block

$$= \frac{(30*15+20*15)}{30} = 25 \text{ KVA}$$

MD 1 at the end of 10.00 = 30 KVA

For MD 2 (Block method)

Demand – 09.00 to 09.30 block =

$$= \frac{(20*15+30*15)}{30} = 25 \text{ KVA}$$

Demand – 09.30 to 10.00 block

$$= \frac{(30*15+20*15)}{30} = 25 \text{ KVA}$$

MD 2 at the end of 10.00 = 25 KVA

Normally MD is reset on the first of every month, i.e., on a Monthly basis.

MICROCONTROLLER BASED MDI

The conventional maximum demand metering used conventional meters with current transformers. The meter worked on a 15 minute average with a pointer which indicated the maximum reached since the last time the pointer was reset.

It has several drawbacks, as:

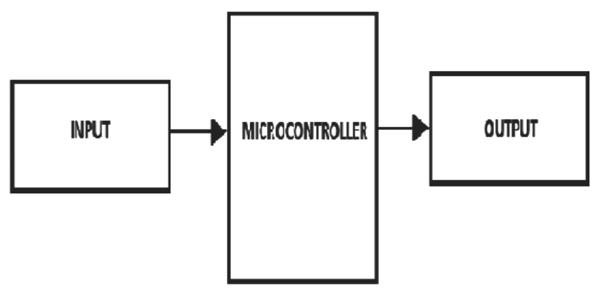
- The meter did not correspond exactly to the supply authority's meter values because of differences in the averaging times and differences in reset times.
- This meter could not be monitored continuously and high maximum demand values were often recorded when problems occurred on the mill and the operator had failed to notice the excessive maximum demand.

- It was very difficult to discover exactly when the maximum demand had been exceeded due to a lack of any recording.
- It was difficult to predict the effects of adding or removing load.

So, a microcontroller based MDI and Controller is introduced.

It calculates the KVA and kW values approximately every minute and displays these on the VDU for the power station attendant or shift electrician to see. Every half hour, at the end of each metering period (after a reset has occurred), the KVA, kW and power factor recorded during that time, is printed by the printer together with a simple graph comparing the actual KVA with the set point (Cobus, 2003; and IOSR, 2012).

Figure 2: Microcontroller Based MDI



METHODOLOGY

Maximum Demand Controller is a device designed to meet the need of industries conscious of the value of load management.

Alarm is sounded when demand approaches a preset value. If corrective measures are not taken, the controller switches off non-essential loads in a logical sequence.

Demand control scheme is implemented by using suitable control contactors. Audio and visual annunciations could also be used.

The load shedding of the feeders can be based on several logics which lead to the development of different strategies for the demand controllers.

For designing the MDI there are three main strategies for calculation of MDI As:

Fixed Priority Strategy

A Fixed priority strategy not only sheds the least important loads first and the most important load last.

The fixed priority strategy has the advantage of keeping high priority areas supply "ON" while low priority areas will be "OFF" during peak demand periods.

Rotating Strategy

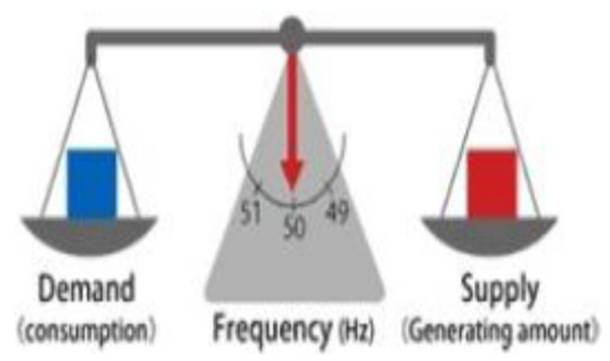
In a rotating strategy, an equal distribution of power is provided to all controlled loads. This strategy is suitable when all areas rooms require an equal share of power.

Combination Fixed/Rotate Strategy

It is the most versatile and powerful strategy because there are so many possible combinations. A combination load strategy allows groups of rotating loads to be programmed with or without fixed priority loads. This can result in the maximum efficiency and energy cost savings.

In addition to the measurement of the MDI this project has a capability of frequency detection and indication as there is a close relationship between the frequency and the power (demand/supply) which is shown in Figure 3 below:

Figure 3: Relationship Between the Frequency and Power (Demand/Supply)



ELECTRICAL LOAD MANAGEMENT

Need for Electrical Load Management

In a macro perspective, the growth in the electricity use and diversity of end use segments in time of use has led to shortfalls in capacity to meet demand. As capacity addition is costly and only a long time prospect, better load management at user end helps to minimize peak demands on the utility infrastructure as well as better utilization of power plant capacities.

The utilities (State Electricity Boards) use power tariff structure to influence end user in better load management through measures like time of use tariffs, penalties on exceeding allowed maximum demand, night tariff concessions, etc. Load management is a powerful means of efficiency improvement both for end user as well as utility.

As the demand charges constitute a considerable portion of the electricity bill, from user angle too there is a need for integrated load management to effectively control the maximum demand (Brown, 2008; and Steve *et al.*, 2010).

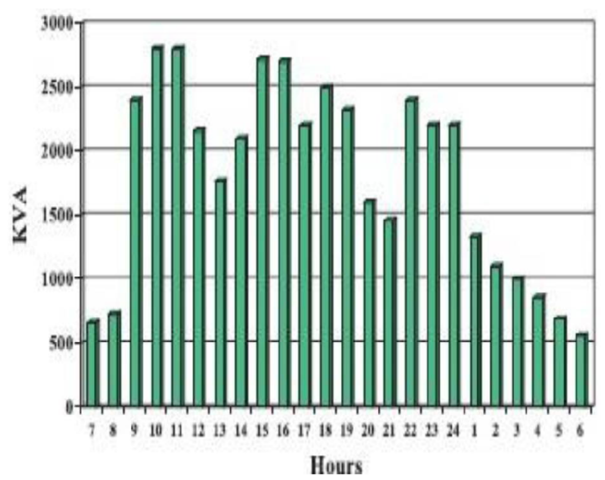
MAXIMUM DEMAND CONTROL

Step By Step Approach for Maximum Demand Control:

Load Curve Generation

Presenting the load demand of a consumer against time of the day is known as a 'load curve'. If it is plotted for the 24 hours of a single day, it is known as an 'hourly load curve' and if daily demands plotted over a month, it is called daily load curves. These types of curves are useful in predicting patterns of drawl, peaks and valleys and energy use trend in a section or in an industry or in a distribution network as the case may be.

Figure 4: Load Curve



Rescheduling of Loads

Rescheduling of large electric loads and equipment operations, in different shifts can be planned and implemented to minimize the simultaneous maximum demand. For this purpose, an operation flow chart and a process chart are prepared. Analyzing these charts and with an integrated approach, will help to improve the load factor which in turn reduces the maximum demand.

Storage of Products/in Process Material/Process Utilities Like Refrigeration

It is possible to reduce the maximum demand by building up storage capacity of products/materials, water, chilled water/hot water, using electricity during off peak periods.

Shedding of Non-Essential Loads

When the maximum demand tends to reach preset limit, shedding some of non-essential loads temporarily can help to reduce it. Sophisticated microprocessor controlled systems are also available, which provide a wide variety of control options like:

- Accurate prediction of demand.
- Graphical display of present load, available load, demand limit.
- Visual and audible alarm.
- Automatic load shedding in a predetermined sequence.
- Automatic restoration of load.
- Recording and metering.

Operation of Captive Generation and Diesel Generation Sets

When diesel generation sets are used to supplement the power supplied by the electric utilities, it is advisable to connect the DG sets for durations when demand reaches the peak value. This would reduce the load demand to a considerable extent and minimize the demand charges.

Reactive Power Compensation

The maximum demand can also be reduced at the plant level by using capacitor banks and maintaining the optimum power factor. Capacitor banks are available with microprocessor based control systems. These systems switch on and off the capacitor banks to maintain the desired Power factor of system and optimize maximum demand thereby (Calcutt *et al.*, 1998; and Cobus, 2003).

POWER FACTOR IMPROVEMENT AND BENEFITS

Power Factor Basics

In all industrial electrical distribution systems, the major Loads are resistive and inductive. Resistive loads are incandescent lighting and resistance heating. In case of pure resistive loads, the voltage (V), current (I), resistance (R) relations are linearly related,

i.e.,

Voltage (V) = IR

and Power (kW) = VI

Typical inductive loads are AC Motors, induction furnaces, transformers and ballast-type lighting.

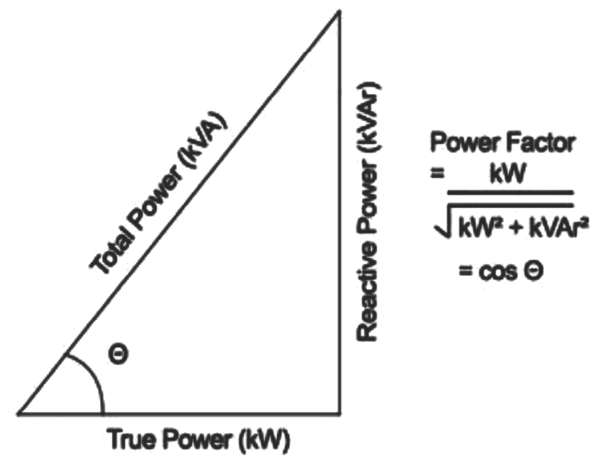
Inductive loads require two kinds of power:

1. Active (or working) power to perform the work, and
2. Reactive power to create and maintain electromagnetic fields.

Active power is measured in kW (Kilo Watts). Reactive power is measured in kVAr (Kilo Volt-Amperes Reactive).

The vector sum of the active power and reactive power make up the total (or apparent) power used. This is the power generated by the SEBs for the user to perform a given amount of work. Total Power is measured in KVA (Kilo Volts-Amperes).

Figure 5: Power Triangle



The active power (shaft power required or true power required) in kW and the reactive power required (KVAR) are 90° apart vectorically in a pure inductive circuit, i.e., reactive power KVAR lagging the active kW. The vector sum of the two is called the apparent power or KVA, as illustrated above and the KVA reflects the actual electrical load on distribution system (Brown, 2008).

The ratio of kW to KVA is called the power factor, which is always less than or equal to unity. Theoretically, when electric utilities supply power, if all loads have unity power factor, maximum power can be transferred for the same distribution system capacity. However, as the loads are inductive in nature, with the power factor ranging from 0.2 to 0.9, the electrical distribution network is stressed for capacity at low power factors.

IMPROVING POWER FACTOR

The solution to improve the power factor is to add power factor correction capacitors to the plant power distribution system.

They act as reactive power generators, and provide the needed reactive power to accomplish kW of work. This reduces the amount of reactive power, and thus total power, generated by the utilities.

ADVANTAGES OF PF IMPROVEMENT BY CAPACITOR ADDITION

- Reactive component of the network is reduced and so also the total current in the system from the source end.
- I^2R power losses are reduced in the system because of reduction in current.
- Voltage level at the load end is increased.
- KVA loading on the source generators as also on the transformers and lines up to the capacitors reduces giving capacity relief. A high power factor can help in utilising the full capacity of your electrical system (Calcutt *et al.*, 1998; and Mc Donald, 2003)

COST BENEFITS OF PF IMPROVEMENT

While costs of PF improvement are in terms of investment needs for capacitor addition the benefits to be quantified for feasibility analysis are:

- Reduced KVA (Maximum demand) charges in utility bill.
- Reduced distribution losses (KWH) within the plant network.
- Better voltage at motor terminals and improved performance of motors.
- A high power factor eliminates penalty charges imposed when operating with a low power factor.
- Investment on system facilities such as transformers, cables, switchgears, etc., for delivering load is reduced.

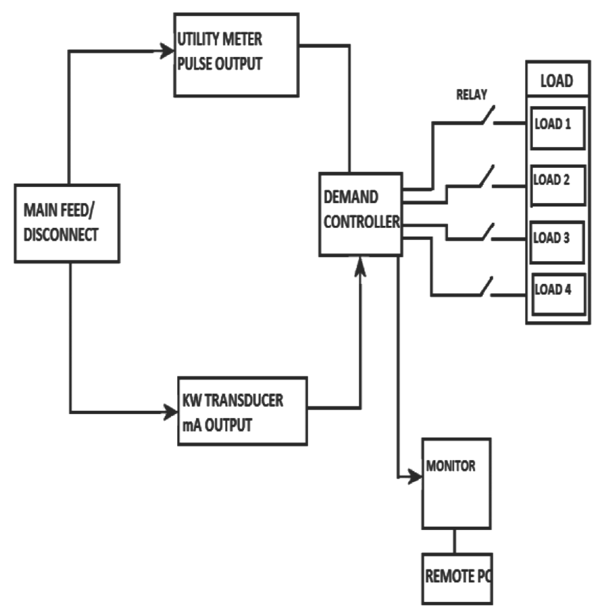
MAXIMUM DEMAND CONTROLLER

High-Tension (HT) consumers have to pay a maximum demand charge in addition to the usual charge for the number of units consumed. This charge is usually based on the highest amount of power used during some period (say 30 minutes) during the metering month. The maximum demand charge often represents a large proportion of the total bill and may be based on only one isolated 30 minute episode of high power use.

Considerable savings can be realised by monitoring power use and turning off or reducing non-essential loads during such periods of high power use.

Maximum Demand Controller is a device designed to meet the need of industries conscious of the value of load management. Alarm is sounded when demand approaches a preset value. If corrective action is not taken, the controller switches off non-essential loads in a logical sequence. This sequence is predetermined by the user and is programmed jointly by the user and the supplier of the device. The plant equipments selected for the load management are stopped and restarted as per the desired load profile. Demand control scheme is implemented by using suitable control contactors. Audio and visual annunciations could also be used.

Figure 6: Demand Controller



CONCLUSION

A good record of the load pattern is obtained which enables accurate predictions and better load distribution. The capital outlay for maximum demand control is low. With good maximum demand indication, it is possible to create awareness of where and when power is used and consequently gets greater power utilization. The data obtained from the MDI controller may be used for the design and development of Smart Grid. Helpful for prediction of estimated load in large load dispatch centre.

Proper utilization of electrical power during off peak period. The data obtained from the MDI controller is useful for the automation of Distribution system.

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