LOAD MANAGEMENT DSM: PAST, PRESENT & FUTURE

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ABSTRACT

Load Management has grown in acceptance over the past several decades as a reliable means to provide a demand-side resource of demand capacity. This paper first reviews the significant break-throughs of load management technology then sets the stage for a discussion of the cutting edge applications and their place in the upcoming information revolution.

LOAD MANAGEMENT'S PAST

Big Brother

Direct Load Management (control activated by the electrical utility to the residential consumer's appliance) has its origin in American Utilities in the 1960's. By the mid-seventies, most U.S. utilities were aware of successful programs but were skeptical that their residential customers would tolerate the expected inconveniences. Other skeptics did not anticipate that true demand reduction would be realized economically. Some local newspapers went as far as to taint the proposed Programs "Big Brother" referring to the George Orwell novel 1984. As the number of Direct Load Management installations grew, skeptical fears were replaced with timid pilots that in turn became successful full-scale programs.

Single-Tone & Two-Tone Systems

In the beginning, Load Management was simple. By broadcasting an analog tone on a specific radio frequency, Utilities were able to activate Load Control Receivers (LCRs) at each participating residence. Early Load Management programs discovered that radio frequency interferences were inadvertently created by other machinery in an industrial age and the LCRs were falsely activated by the "noise". Early Load Management systems quickly adopted a two-tone sequence for activation to reduce the "falseing". These two tones were slight variations on a carrier frequency.

Conventional Digital Switches: "100" Technology

In 1976 the advancing digital age technology was applied to the communication of Load Management signals. In a similar manner to the two-tone sequential signal, a digital signal would be broadcast on the carrier frequency. This digital signal was modulated with a technique known as Frequency Shift Keying between mark and space, two different frequencies internal to the carrier frequency envelope. The mark and space frequencies became the digital "1" and "0" building blocks that paved the way for the construction of increasingly intelligent signaling. The first digital switches were introduced by Scientific-Atlanta in 1977.

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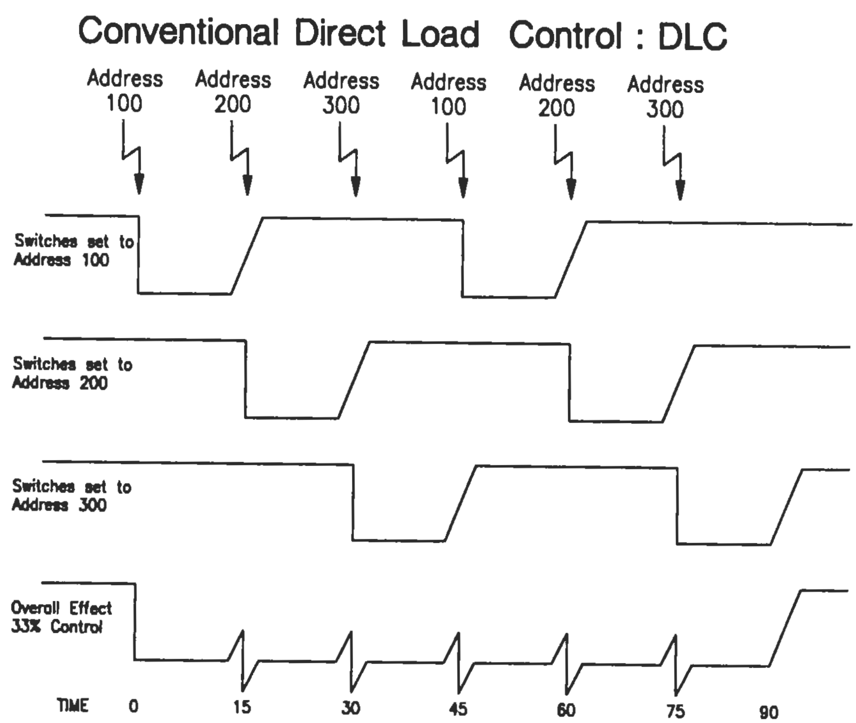
Typical deployments of these early digital load control receivers required the population of switches to be segregated into three to ten different load groups. These load groups (separated by physically programming each switch to one of several digital operational addresses) were necessary to cycle off a fraction of the controllable load while the remaining fractions of controllable load were allowed electricity.

These early load management receivers would be physically programmed by an installation contractor to switch off load for a pre-determined length of time (7.5, 15 or 30 minutes at a time). Each receiver would vary the exact control time ±90 seconds so that a large population of appliances demanding electricity would blend back into the load profile over three minutes rather than becoming completely synchronized. In order to achieve a longer control period than the programmed time, a "refresh" signal received during the original control period would reset the internal timer back to zero. Figure 1 depicts the intentionally sloppy time-out as a sloped edge coming out from control. The sloped edge indicates that some of the LCRs will time-out at the setting minus 90 seconds while the others will time-out throughout the next three minutes (up till the setting plus 90 seconds.) The arrows in figure 1 depict the radio signals as they are broadcast to the particular addresses.



DLC 33% Control "Balanced" with Three Addresses.
Switches set to Time Out of 15 minutes ±90 sec.

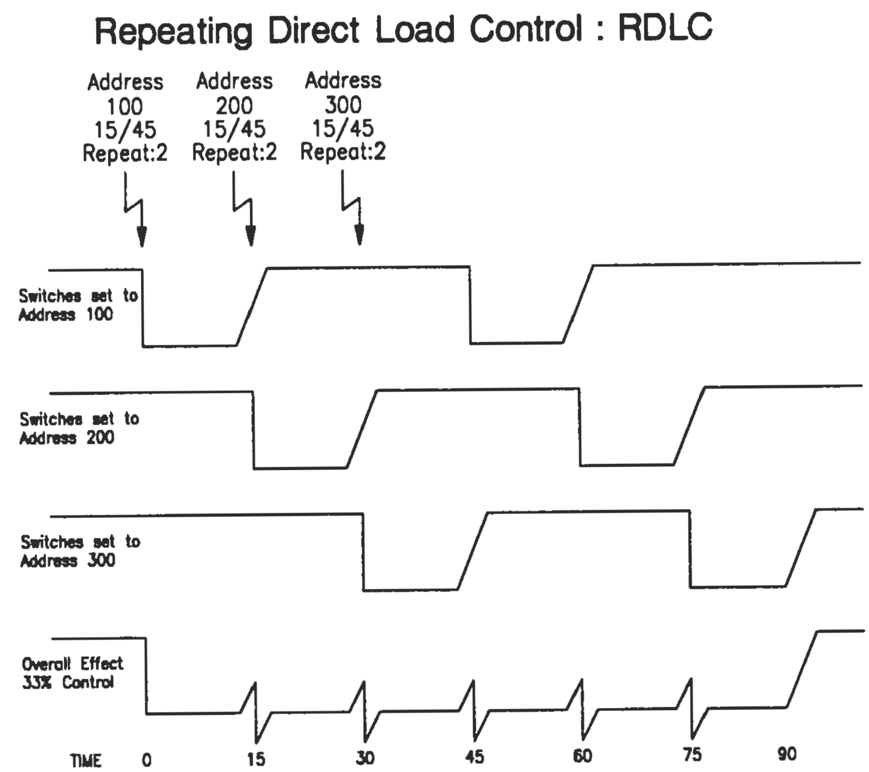
Figure 1

In order to achieve an ON/OFF cycling pattern with these conventional Load Management receivers, a new broadcast was required for each operational address at the beginning of each control cycle. This basic load control technology has become known as the "100" type switches denoting the first digital load control technology.

Repeating Load Control Switches: "101/102" Technology

Although functional, the conventional method of resetting timers and cycling load by groups and addresses was extremely intensive on the communication system. Multiple radio broadcasts were required every five minutes during load peaking season. In order to alleviate the increasing log-jam of signals, the digital message was lengthened to include cycle ON/OFF instructions as well as a number of repetitions of that strategy to implement.

These repeating load control switches (know as "101/102" technology) could achieve various patterns of load management cycling based on the specific instructions received. Moreover, the same switch could cycle an appliance with different patterns. For example, a switch could control its load 10 minutes off out of 30 minutes for four hours one day and then 15 minutes off out of 30 minutes for three hours the next day.



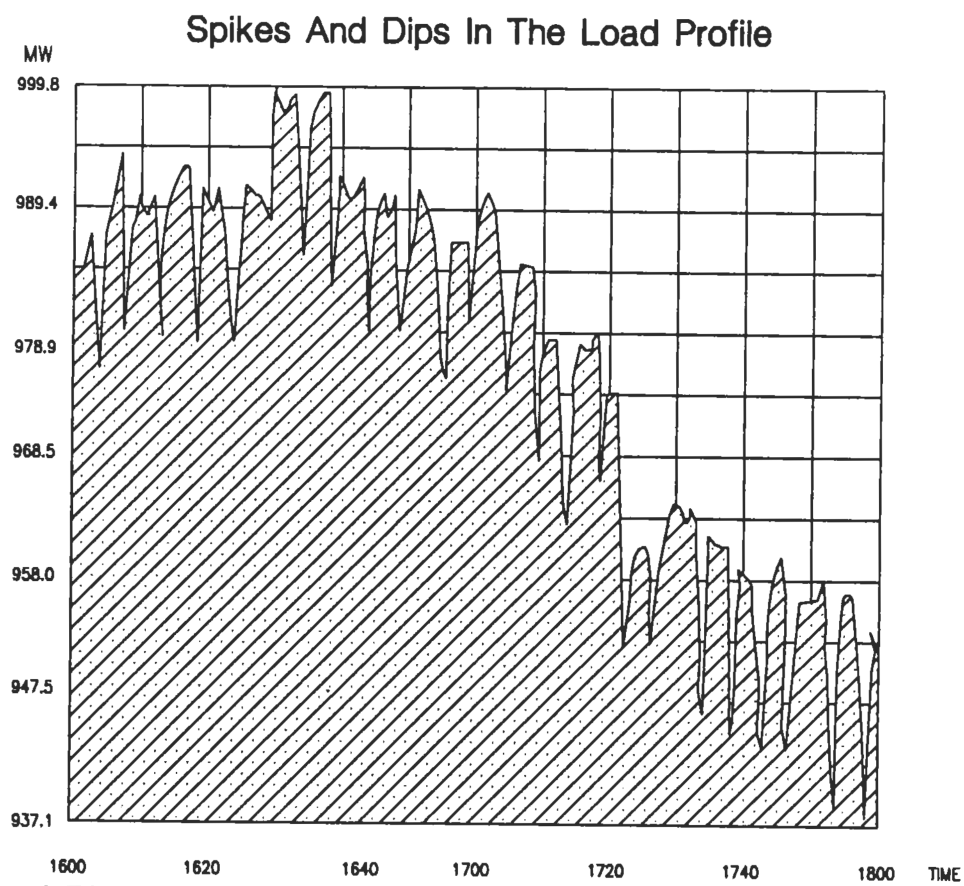
RDLC 33% Control "Balanced" with Three Addresses.
Received Message: 15 minutes off out of 45 minutes, Do Twice.

Figure 2

The "101/102" Repeating Load Control Method (developed in 1980 by a joint effort of General Electric and Scientific-Atlanta) significantly reduced the burden on the communication system and released a lot of air-time for other applications or other users of a shared frequency.

Conventional Problems with the Groups and Addresses "100" & "102" Technologies

As the population of load control receivers grew, so did some inherent problems with the conventional address scheme of separating controlled load into a small number of groups differentiated by the operational address. While the amount of load under control grew, the load controlled in each group had to be balanced. This balancing was not straight-forward since each LCR controlled varying amounts of load. Also, as one group of switches changed from "OFF" to "ON", the next segment of controlling switches had to be timed to initiate their control half-way into the ±90 randomization of the time-out period of the preceding group. Even at its optimum, this method created spikes and dips in the demand and voltage profiles during this transition. As the amount of controlled load grew, so did these spikes and dips in the electrical profiles creating greater harmonic disturbances.



Spikes and Dips in the Load Profile : Caused by transition between groups and the amount of load controlled by each address becoming unbalanced.

Figure 3

At the same time, a second problem emerged that crippled large-scale load control programs' conventional method of juggling groups of operational addresses. As the controlled appliances were returned to uninhibited consumption, they would need to run continuously until their temperature requirements were satisfied. The extra run time was good in order for the utility to recapture some deferred kWh sales, but it created a post-control peak demand that negated most of the benefits of the original control.

Specifically, larger amounts of load were being controlled by the same number (3-10) of operational addresses. As the last load group was released from control, a significant amount of electrical demand stressed the system that was still working to satisfy the preceding load groups. Post control peaks would often exceed the peak during control. Figure 4 is derived from the experience of a mature load control program. Notice the "payback" is forty megawatts greater than the "controlled" peak.

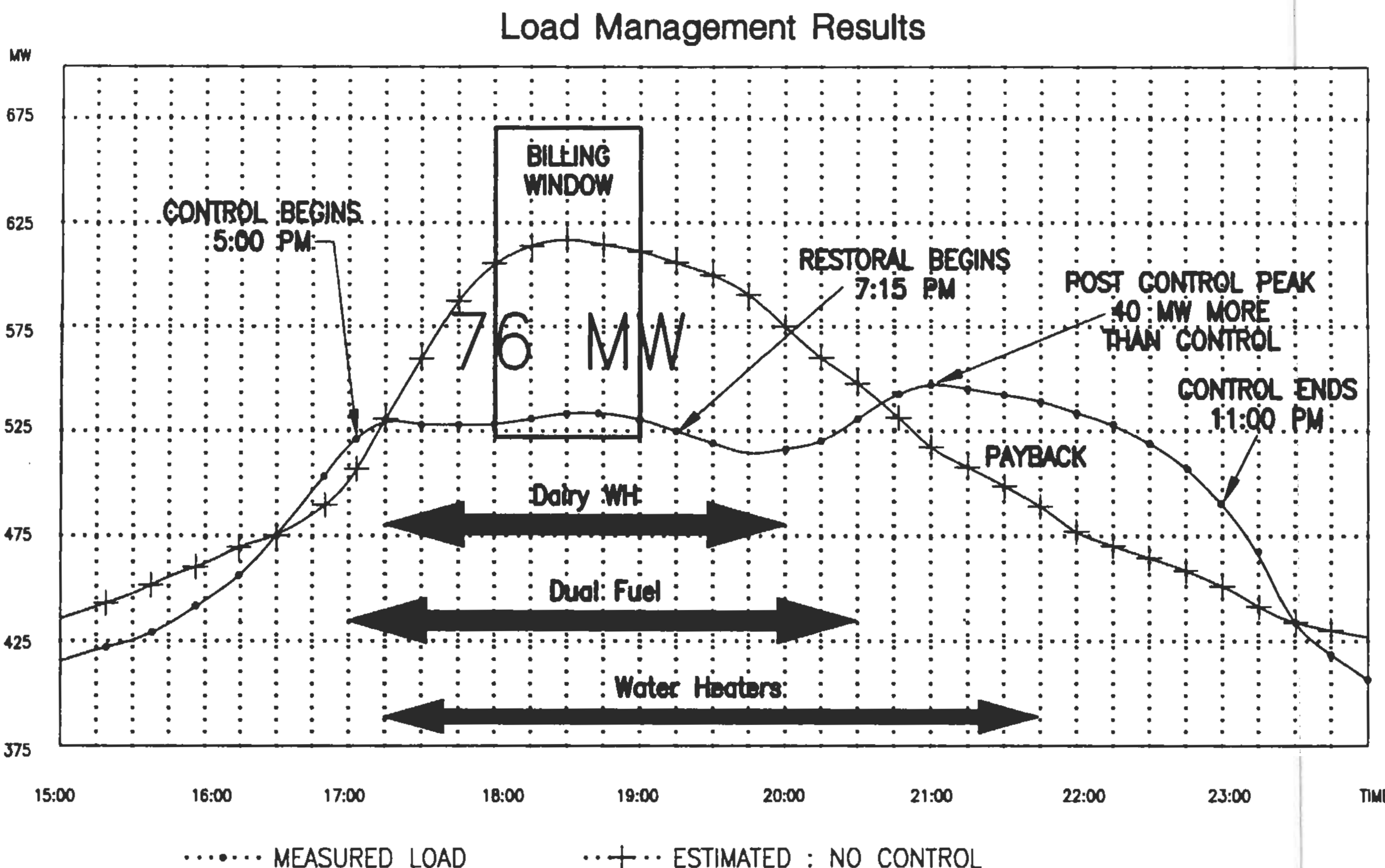
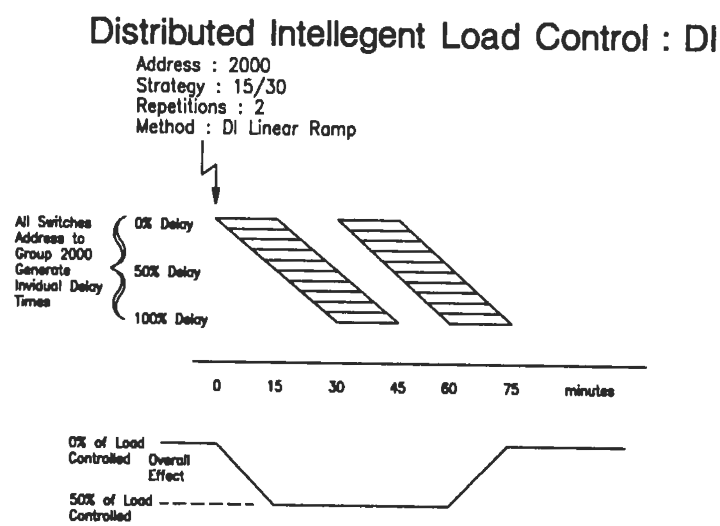


Figure 4

Distributed Intelligence: "105" Technology

The initial answer to the "spikes and dips in the profile" as well as the "post-control peak" was to create a new set of operational addresses, program any new installation with one of the new addresses and then go back to a large number of existing installations to physically reprogram those switches to one of the new addresses. The ultimate resolution of these problems was the creation of "Distributed Intelligent" switches known as "105" technology (developed in 1988 by Florida Power Corp. & Scientific-Atlanta.) A distributed intelligent switch population will all receive an ON/OFF cycle strategy with a number of repetitions at the same time, but each switch will wait a random percentage of the cycle period before starting the cycling pattern.

In effect, all the switches programmed to respond to a particular operational address will behave as if there were multiple addresses spreading out of their control. As a group, the load profile would ramp linearly into and out from control. Figure 5 depicts the aggregate effect of a distributed intelligent (DI) switch population with the control period of each switch drawn as a solid line in the order of their random start time.



Smooth Linear Ramping Into And Out From Control.
All Switches Programed To Same Address : Balanced
Figure 5

For the first time, operational addresses could be used to differentiate different geographical districts, substations, service areas, or even feeder circuits. Cycled load groups were automatically balanced for the first time.

True distributed intelligence includes smoothing algorithms so that the overall effect of the load control population can make a graceful transition from one cycling strategy to a more aggressive strategy, a less aggressive strategy, or merely a different duration of control than originally downloaded. These essential smoothing algorithms blend in the new instructions as the target for the distributed intelligent switches to migrate towards as a population by acting independently. Basically, the intelligence that formally would reside in the Utility Computer, installation contractors programming, and the communication system's timing were distributed out to each switch location in order to make possible a smooth control of a large block of load.

Since the full day of load management could be accomplished with a single, one second message, many utilities added the load management application to their existing voice channels used for communications to the line trucks or paging. The communications electronics were adapted by listening to the airways before sending out the load control signal. By using "listen-before-talk" circuitry and by piggy-backing on an existing frequency, Distributed Intelligent "105" type, switches achieve advanced cost efficiencies for utilities utilizing existing communications systems.

Remote Re-addressability: "205" Technology

Once Distributed Intelligent switches were deployed throughout a load control program, operational addresses could be used to differentiate and control load specific to a particular segment of the utility's service area. However, as the distribution network continued to evolve, substation boundaries would shift and the load control receivers in the effected area would need their operational addresses reprogrammed to coordinate with the revised service area. Once again, based on the digital building blocks of the "100" type message and making use of advanced microprocessors, the signal was extended to incorporate remote programming of the operational addressing scheme.

Remote re-addressability, known as "205" type technology (developed by Scientific-Atlanta in 1990) produced other efficiencies to Load Control Programs. For the first time, offering different programs (different cycling percentages for varying incentives) was manageable. As electrical consumers decided to shift programs, their requests could be taken care of without a utility employee having to physically visit their switch. The operational addressing is delivered to a "205" type switch over the same radio system that delivers the load control strategies. Utility customers have always requested to be temporarily dropped

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from the load control program but be reinstated after their visiting elderly relative is gone or their spouse recovers from surgery (ect.). Using the "205" method these requests can be handled promptly and without inconvenience to the customer or the utility. The customer may have to forgo that year's incentive, but they do not require additional service visits to participate in the future.

Simulcast Frequency Sharing: "206" Technology

Throughout the early years of load management the radio broadcast from adjacent transmitters were sequenced to occur at different times so that the signals from neighboring transmitters did not interfere with each other at a load control receiver location. Within the past few years, utility communications technology has developed the capability to simulcast the same signal from a number of adjacent transmitters without the signals interfering. The most common utility application of simulcast communications is a digital paging network. Simulcast capable load control receivers, known as "206" type technology (developed in 1992 by Scientific-Atlanta), were developed to make use of these existing communications systems.

Utilities that do not currently own and operate their own communications systems may choose to contract their broadcast service from a local paging provider. For a monthly fee, the utility is connected into the paging network of transmitters and the digital load control message is simulcast as if it were a page. In order to allow several utilities to make use of the same paging provider, the "206" technology includes a "utility address". Several different utilities can make use of the same operational addresses on the same paging frequency based on their separate utility address codes inherent to the "206" technology.

LOAD MANAGEMENT'S PRESENT

LM System Applied to Other Applications

Today, several million American homes have a load control receiver on one or more electrical appliances. Load Management programs have expanded to control a variety of residential electrical appliances as well as commercial loads. The existing load management systems have also been applied to achieve other areas of Distribution Automation such as the notification to interruptable curtailment customers, the remote switching of distribution capacitor banks and the remote reconnect/disconnect of an entire house's 200 Amp Service. Figure 6 lays out the basic application areas of Distribution Automation. Each of these applications require different mixes of control (one-way) and monitoring (two-way) capabilities.

DISTRIBUTION AUTOMATION'S AREAS OF APPLICATION

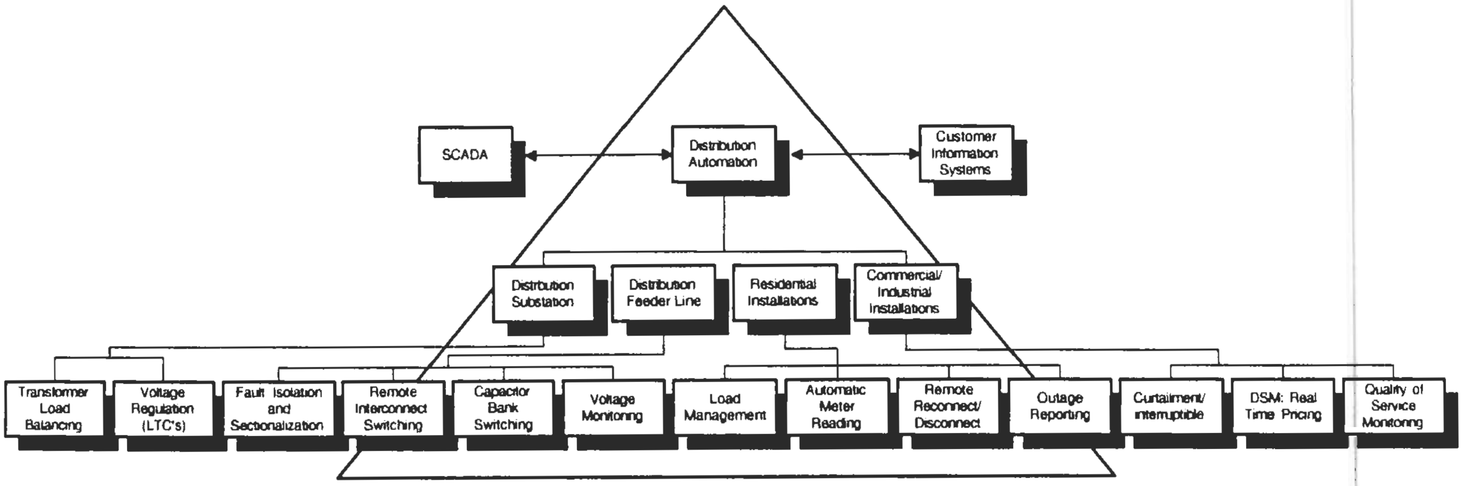


FIGURE 6

Incentives Paid & Demand Reduction Benefits

Residential load control programs are traditionally deployed by enticing the homeowner with a rebate/credit of five to fifty dollars a year. In effect, the utilities are sharing their savings with the participants of the program. Several current load control programs have discovered that the best marketing method is a "direct mailing" that gets across the message "Load Management will help keep everyone's electrical rates low." The offer of the rebate may catch the consumers' eye, but the opportunity to keep their rates from rising will prompt their action and participation. The following charts depict the typical credits paid out and the typical demand reduction per appliance.

Incentives Paid To Participants

Load Type	Avg. Credit ($/yr)	Range ($/yr)
Air Conditioners	22	8 - 72
Water Heaters	27	6 - 60
Space Heaters	25	6 - 72
Swimming Pool Pumps	28	10 - 42

Figure 7

Demand Reduction Benefits Of Load Control

Load Type	Avg. Reduction	Range
Air Conditioner	0.97 kW	0.44 - 1.50 kW
Water Heater (summer)	0.60 kW	0.25 - 1.00 kW
Water Heater (winter)	0.97 kW	0.27 - 1.50 kW
Space Heaters	1.04 kW	1.00 - 1.10 kW

Figure 8

The Need for a Feedback Loop of Results

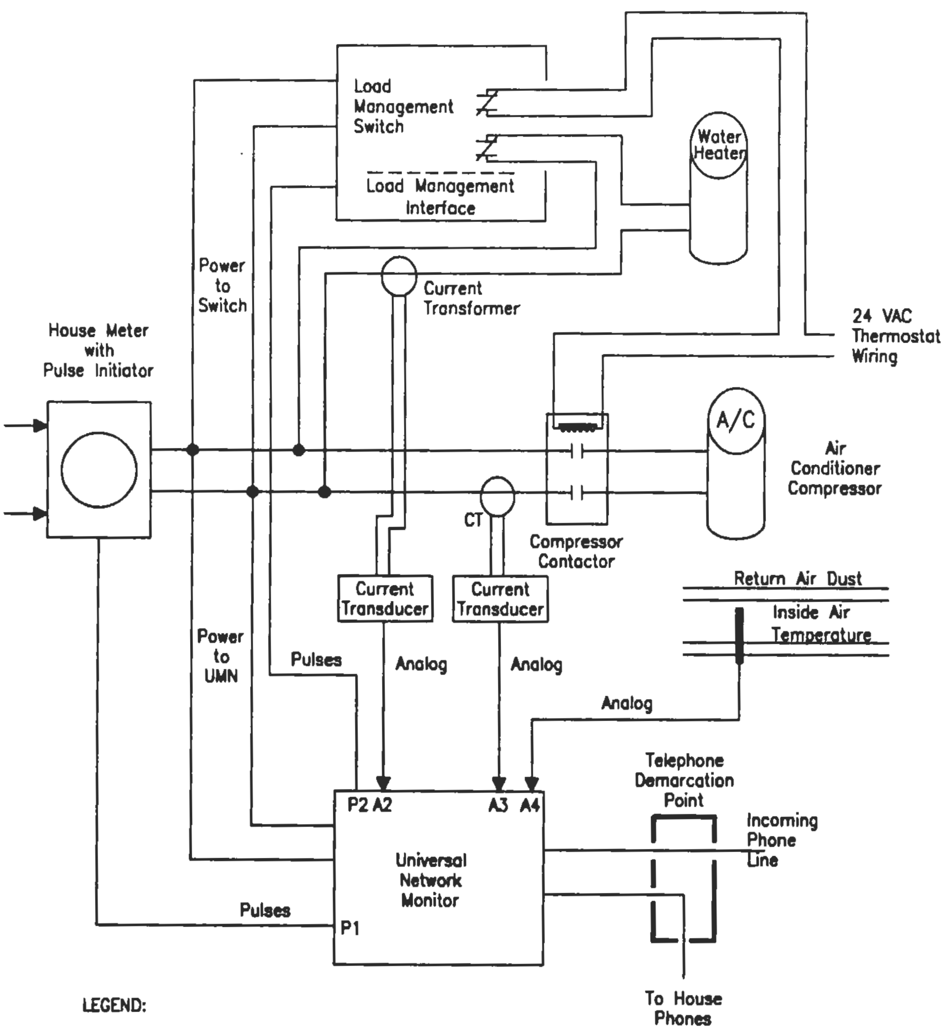
Modern Load Management Systems have incorporated the functionality of measuring the demand reduction achieved at a sampling of the residences and compiling the results before the next day's control. Monitoring end-of-month data has always occurred during the first phase of implementing a new load control program, but recently, utilities are keeping a feedback loop of measured demand reductions from a statistically valid sampling of the ongoing load control receiver population. This information is useful during "near peak" days where all-out load deferral is not required but a dispatchable amount of load might figure into the utility's resource dispatcher's decision. By providing the utility resource dispatcher with quantified last-day or like-day information, they can make shrewd decisions about using the dispatchable demand-side resource of the existing load control receiver population as opposed to starting up a peaking plant, scheduling a purchase or buying "spot" demand off of the power grid.

There are two critical parts to accomplishing this near-real time monitoring. First, the switch activity and the appliance activity must be measured independently. Secondly, these two profiles must be communicated back to the utility within twelve hours and at a reasonable cost. A break-through in the monitoring of the switch activity was announced at the 1993 DA/DSM International Symposium: a Load Management Interface (LMI) between the switch and the recorder.

Load Management Interface (LMI) Reduces Feedback Costs

An initial dilemma arose from the random start time of distributed intelligent (DI) switches. Since a DI switch delays a different duration each time it initiates linear control, the actual switch relay needs to be monitored. There was no way to know whether the appliance was not drawing electricity because its thermostat was satisfied or whether the LCR prevented the electrical demand. At the 1993 DA/DSM conference, Scientific-Atlanta introduced the industry's first Load Management Interface (LMI) circuit board which fits in a standard load control receiver and outputs pulses based on the status of the controlling relay. The LMI pulses can then be collected with the same standard load profile recorder which is also documenting the appliance consumption. The break-through was that the actual demand reduction accomplished by that particular appliance could be measured and reported. The following diagram depicts the one-line diagram and the channels of information for an LMI installation.

Load Management System Monitoring



LEGEND:

P1 = Pulse Channel 1 (Whole House KWH)
P2 = Pulse Channel 2 (Switch Activation)
A1 = Analog Channel 1 (Voltage)
A2 = Analog Channel 2 (Water Heater KWH)
A3 = Analog Channel 3 (Air Conditioner KWH)
A4 = Analog Channel 4 (Inside Air Temperature)

Load Management Interface (LMI) connects switch activity as well as appliace activity to remote monitoring channel recorder

Figure 9

Before the LMI made a direct link to the switch activity, both a controlled house and an uncontrolled house had to be monitored and reported for comparison. The comparison lost a level of credibility by assuming the two houses and families were identical. By making use of an LMI board, only the controlled home needs to be monitored. Now "next day" results are reliable and affordable.

LOAD MANAGEMENT'S FUTURE

The Information Highway

The foreseeable future of load management technology includes connection into the upcoming "information highway." As providers of communications services such as cable TV and telephone systems compete to connect American homes into their networks, all-encompassing "gateways" into the home will include Load Management capabilities. Other Distribution Automation functionality is expected to be included in the Information Highway gateway. The gateway will likely include Automatic Outage Reporting, Automatic Meter Reading, Quality of Service Monitoring and possibly Real-time Rates notification.

The Utility Channel

Imagine the home of the future with a TV lineup including The Utility Channel (TUC). The Utility Channel may include up-to-date usage for that particular home, an expected monthly bill based on present reading and historical data, projected rate for each of the next twenty four hours, a history of electrical interruptions and announcements of new programs. Not all Americans understand the difference between a kW and a kWh, but we all can relate to a TV giving us information about our existing cost and purchase/participation opportunities.

Premium Services

The Utility Channel may be a little far-fetched, but the interconnection of homes is real. The anticipated "gateway" is a modular design so that the homeowner can pick from a smorgasbord of "premium services." One group of Investor Owned Utilities currently plans to penetrate one fourth of all of their electrical customers with an interactive gateway. The next question is what will the future hold for the remaining three quarters of American households? Quite simply, we are already there. For the homes that choose not to hook into the information highway, they can still benefit from Utility Distribution Automation with a collection of separate devices that have already proven themselves independently.

Open Access

The impact of the upcoming "Open access", in any incarnation, will only fuel the competitive fires. Any Distribution Automation or Premium Service that is cost effective or generates revenue will be continually refined and expanded. Load Management's piece to that puzzle is secure since it is already cost effective and can only improve.

If "open access" means that utilities will go hunting for residential customers the way telephone companies are doing now, Utilities with healthy load control programs will be more competitive.

The future of the switch itself may be the addition of some individuality. This could mean that the local device is constantly monitoring its own environment and alleviating an aggressive control strategy if the house gets too warm or cold. Again this automatic override would be a premium service which would require an ongoing fee to offset the additional hardware costs.

CONCLUSION: THE PAST IS PROLOG

The National Archives in Washington D.C. has this simple inscription on its edifice: "THE PAST IS PROLOG." This discussion of Load Control technology can be summarized with the same words. Without knowing exactly what the next hurdle will be, we can assume that the utilities and LCR manufacturers will jointly develop a solution. As Load Management programs become the standard rather than the exception among American utilities, more residential consumers will overcome their reluctance to help out. Continual education of the rate benefits coupled with a neighbor's testimony of satisfaction will eventually win over the doubters. Just think of it! The more of us participating, the greater the rate benefit and the less each of us is controlled.