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The Development of Intelligent Direct Load Control System

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Abstract

The electric utility has the responsibility of reducing the impact of peaks on electricity demand and related costs. Therefore, they have introduced Direct Load Control System (DLCS) to automate the external control of shedding customer load that it controls. Since the number of customer load participating in the DLC program are keep increasing, DLCS operators a
re facing difficulty in monitoring and controlling customer load. The existing DLCS needs constant operator intervention, e.g., whenever the load is about to exceed a predefined amount, it needs operator's intervention to control the on/off status of the load. Therefore, DLCS operators need the state-of-the-art DLCS, which can control automatically the on/off status of the customer load without intervention as much as possible. This paper presents an intelligent DLCS using the active database. The proposed DLCS is applying the active database to DLCS which can avoid operator's intervention as much as possible. To demonstrate the validity of the proposed system, variable production rules and intelligent demand controller are presented.

Keywords: *Direct load control, Production rule, Active database, Intelligent direct load controller*

1. INTRODUCTION

In Direct Load Control (DLC) programs, a utility as a programs' sponsor can remotely interrupt customer load at the time of peak load by DLCS operators. In return for customer's inconvenience, utility gives an incentive payment or credit. The existing DLCS has some system architectural weaknesses with regard to DLC system management, e.g., its system architecture is designed using a passive database system. A passive database has been widely used as a reporting tool and a monitoring tool because of its easiness for handling massive amounts of data. But its commands are executed by the database query (or delete or update) which is only requested by the user or program. Whenever the conventional DLCS forecasts that the amount of customer load is going to exceed a predefined amount, it remotely controls the on/off status of the load by a DLCS operator's request or DLC program. Likewise, the conventional DLCS always needs constant operator's attention and intervention. Therefore, it may happen that even an experienced operator fails to control the on/off status of the load due to his/her miss judgment.

This paper, presents a DLCS design method using the active database to manage massive customer data in an active manor and control automatically the on/off status of the customer load at the time of peak load without operator's intervention as much as possible. Main steps to design the new DLCS have been implemented in two

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stages. First stage is to define the production rules which can avoid operator's intervention as much as possible and manage massive customer load data actively. Second stage is to design system architecture using active database, which can be easily applied to the conventional DLCS. An Intelligent demand load controller is implemented to demonstrate the validity of the proposed production rules and DLCS design architecture.

2. A PRODUCTION RULES FOR DLCS

The production rule paradigm originated in the field of Artificial Intelligence (AI) with expert systems languages such as OPS5 (Kang and Kim,2004). The production rule consisted of three components: an event, a condition and an action. When customer load data in the database is updated on-line, there are three kinds of component procedure for monitoring the updated data. An event component detects online update of the customer data. And a condition examines update's validation. If the condition has evaluated the update to be true, then an action is carried out for the described task. By using the E-C-A (Event-Condition-Action) rules, a DLCS using active database can monitor and control the status customer load without user's intervention. Generally, an E-C-A rule has the following features:

- Event: An event describes a happening to which the rule may be able to respond and it occurs when data in database is changed by the database query (update, insert, delete) or application program. One event can trigger more than one rule.
- Condition: When rules are triggered by an event, the condition part of the rule checks the event's context. If the condition is satisfied, then the action of the rule is executed.
- Action: An action specifies what to be carried out by the rule when the rule is triggered and its condition is satisfied.

It can be sequence of retrieval and modification commands over any data in the database and it can cause triggering another rules and application programs. An example of applying for DLCS is as follows.

Rule) If a customer load demand is going to exceed its projected amount of load then DLCS disconnect the customer load:

- Event: Update to customer load demand data
- Condition: customer load demand data > projected customer load data
- Action: Disconnect the customer load for the brief period of time.

2.1 The Requirement Gathering and Conceptual Design for DLCS Database

The main objective of requirement gathering is collecting the data used by an organization, identifying relationships between data and future data need. This process is initialized by interviewing the user of the organization. The required data tables and attributes for DLCS database is as follows:

- Intelligent demand controller (IDC): IDC ID, Customer ID, Load ID, On/off status (1: on, 0: off), Present active power, Present accumulated active power, Projected accumulated active power, Forecasted accumulated active power, Control failure (0: normal, 1: failure), Communication failure (0: normal, 1: failure).
- Customer: Customer ID, Name, Address, Phone number, The number of load, On/off status (1: on, 0:

off), customer type (residential: 1, commercial: 2), Present Active Power. Present accumulated active power, Projected accumulated active power, Forecasted accumulated active power, Control failure (0: normal, 1: failure), Communication failure (0: normal, 1: failure).

- Load: Load ID, Customer ID, IDC ID, On/off status (1: on, 0: off), Present active power, Control failure (0: normal, 1: failure), Communication failure (0: normal, 1: failure)
- Report: Report ID, Customer ID, Controlled load ID, Time of control ID, Control failure load ID, Control failure IDC ID
- Time of Control: Time of control ID, Month, Day, Year, Time

Where,

Projected accumulated active power: Accumulated active power set by DLCS operator to avoid the customer load demand at the time of peak.

Forecasted accumulated active power: Accumulated active power set by the customer load forecasting application program.

Each tables presented above have the relationships between tables. To illustrate the relationships between the presented tables in a DLCS database, Entity-Relationship(ER) diagram is used in Fig.1.

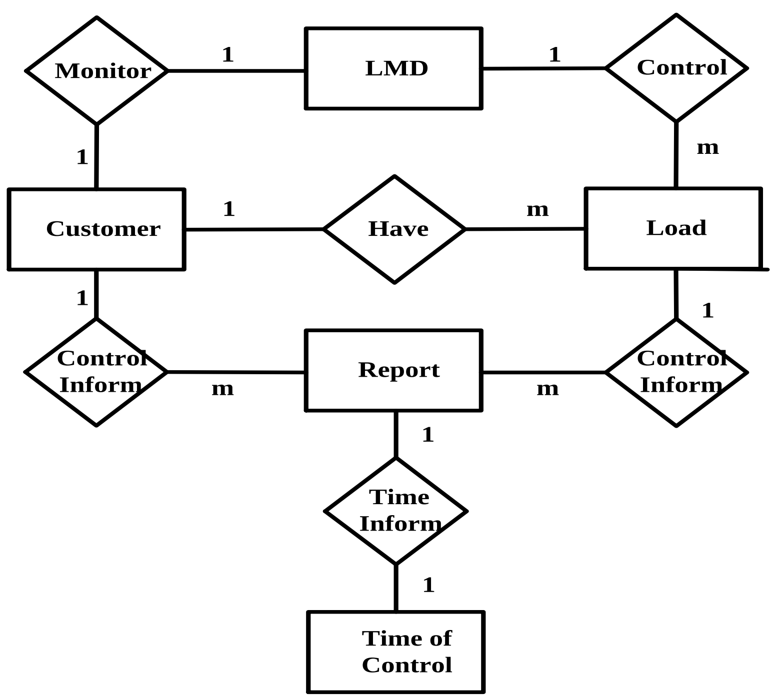

Figure 1. Entity-Relationship(ER) diagram for DLCS database.

2.2 Production Rule Definition

An Intelligent installed in a customer collects the different kinds of state data of electrical equipment such as air conditioners, lighting, motors and pumps. Every customer has one Intelligent demand controller which collects data and sends them to the DLCS database on-line. A production rule checks the telemetered data and fires rules to ensure accuracy and consistency of the data in DLCS database, and it also actives DLC application program to control the on/off status of the load.

When an intelligent demand controller sends the total accumulated active power of customer to DLCS and updates the controller in database on-line, the main system of DLCS calculates the rate of increase for the accumulated active power and forecasts the total accumulated power of load during 900 seconds. Production rules monitor the present state of customer by detecting updated data. If the total forecasted accumulated active power is about to exceed the projected accumulated active power during 900 seconds, then the production rules activate the on/off load control by using the DLC application program and the production rules for direct load control. If a customer has many electrical equipment and its total forecasted accumulated active power is about to exceed its projected accumulated active power, then DLCS have to choose which electrical equipment has to be turned off or cycled to meet the projected amount of active power. The DLC application program decides which electrical equipment among loads to be controlled when total forecasted accumulated active power of a customer is going to exceed its projected amounts.

Rule 1) When IDC sends the present accumulated active power to the DLCS database on-line, the sent data have to be validated by checking the on/off status and communication failure condition:
- Event: send the present accumulated active power to database
- Condition: (the on/off status = on) && (communication failure = normal)
- Action: update the present accumulated active power

Rule 2) When the present accumulated active power is updated, the DLCS activates Forecasting program which calculates the rate of increase for active power and forecasts the total accumulated power of load during 900 seconds.

Rule 3) When Forecasting program presents the forecasted accumulated active power value, that value is updated to intelligent demand controller in the DLCS database

Rule 4) When the forecasted accumulated active power is about to exceed the projected accumulated active power during 900 seconds, DLC application program is executed to meet the projected accumulated active power by choosing an electrical equipment to be turned off or cycled.

Rule 5) When DLCS operator updates the projected accumulated active power of specific customer for special reasons (e.g., customer demand or reducing the impact of peaks on electricity demand), DLC application program is executed if new updated projected accumulated active power of specific customer is less than the forecasted accumulated active power of that customer:
- Event: update projected accumulated active power
- Condition: update (IDC), New projected accumulated active power < forecasted accumulated active power
- Event: execute DLC application program.

Rule 5) When a DLC application program is ended it presents numbers of load ID to be turned off or cycled and triggers updating of the on/off status of load:
- Event: DLC application program
- Condition: True
- Action: update (the on/off status of load = *off*, where the load is to be turned off by DLC application program) && (the on/off status of load = *on*, where the load is to be turned *on* by DLC application

program)

Rule 6) When the on/off status of load is updated by the DLC application program, it triggers updating of the Customer ID, Controlled load ID and Time of control ID of Report:

- Event: update the on/off status of load.
- Condition: update (Load), (New on/off status of load = result of DLC application program.)
- Action: update (the customer ID of report) && (Controlled load ID of Report) && (Time of control ID of Report)

Rule 7) When the on/off status of load is updated to on by the DLC application program, it triggers to turn on the load in customer by sending *on* signal to the IDC device:

- Event: update the on/off status of Load
- Condition: update (Load), (New on/off status of load = result on of DLC application program)
- Action: send *on* the signal to the IDC device

Rule 8) When the on/off status of load is updated to on by the DLC application program, it triggers to turn on the load in customer by sending on signal to the IDC device.

3. THE DEVELOPMENT OF DLCS USING ACTIVE DATABASE

An Intelligent demand controller is developed to demonstrate the validity and effectiveness of the proposed DLCS.

The electric equipment to be controlled by an intelligent demand controller is classified by their characteristics such as air conditioner, ventilation air pumps, an office light, an underground parking lot, a stairway light, etc. And customer can put a priority on each equipment to be turned off when a forecasted active power is about to exceed to the projected active power. The device can collects loads data and sends them to the main system by using wireless network. The developed intelligent demand controller is shown in Fig.2

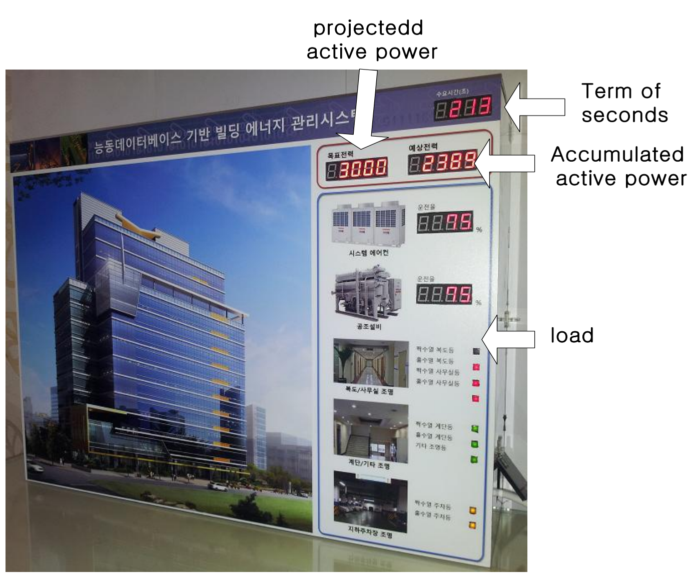

Figure 2. An Intelligent demand controller

5. CONCLUSION

The conventional DLCS always needs operator's intervention whenever customer load demand exceeds a predefined amount. This paper presents Intelligent demand control system using the active database to avoid operator's intervention as much as possible. A various production rules are presented. And an Intelligent demand controller is also developed. Simulation results on eleven loads of a customer shows that the proposed DLCS provides a good performance on the DLCS system without operator's intervention. To validate the proposed DLCS design more realistically, more loads and customers are needed. Since the developed Intelligent demand controller device is only a prototype device and it needs to be tested with more customers

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