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A Practical Investigation on Conservation Voltage Reduction for its Efficiency with Electric Home Appliances

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Abstract

Conservation voltage reduction (CVR) method is a cost efficient solution to reduce the peak demand and power consumption. This method decreases power consumption of electric load by reducing the supply voltage. This method can be used within consumer premises to obtain more efficiency. But CVR cannot be commonly applied for all the electric home appliances. For constant power load CVR method is not suitable. So to test the efficiency of CVR under different electric home appliances, an experiment is done with commonly used electric home appliances. This experiment is done to compare and evaluate the efficiency of CVR the load power consumption values between appliances with CVR and without CVR. The results shows that majority of the home appliances reducing the power consumption with CVR method. Very few appliances tend to increases the power loss after applying CVR method. The detailed result is given in this paper. This results is used to modify the implementation process of CVR method to improve the efficiency. Results concluded that the CVR can be used for reduce the peak demand within consumer side with maintaining consumer comfort level. A new low cost smart plug design is given in this paper for implementing CVR within the consumer side.

Peer-review under responsibility of the scientific committee of the 1st International Conference on Power Engineering, Computing and CONtrol.

Keywords: Conservation Voltage Reduction; Peak Demand; Power Consumption; Energy Savings; Smart Plug; Smart Gird; Voltage Contro Method; Home Energy Management; Smart Meter; Consumer Comfort

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1. Introduction

CVR (also called as Voltage Reduction Method (VRM)) is an easy and low cost method for energy savings and peak demand reduction. CVR method reduces the power consumption by reducing the supply voltage magnitude within the allowed limit. Even though CVR method becoming familiar now a days, but it is not a new topic. CVR method proposed at the time of electricity is started to use in commercial [1]. In past, the CVR method is implemented by utilities to reduce power consumption and to reduce peak demand for maintain the availability of electric power to all of its consumers. But at present, due to latest smart grid technology and advance metering infrastructure, CVR can be implement with in consumer side [2]. Implementing CVR method has its limitation to reach the optimized level of power saving or power consumption. Not all electric home appliances reduces the power consumption, when reducing supply voltage. Some appliances may lead to more power loss. Because the efficiency of 'CVR method' is depends on the characteristic of electric appliances or load. For constant restive load, if the supply voltage is reduced then the power consumption also will reduced. But for constant power load when supply voltage is reduced then the load tends to maintain the power level so current increased which leads to higher energy losses in line [2]. This shows that the utilities cannot be implement the CVR method, because if the utility decreases the supply voltage for all appliances then energy losses occur because some of the home appliances have constant power characteristic. So CVR method is very effective when it is implement to constant resistive load and constant current load. Therefore for optimized implementation of CVR method, the efficiency of CVR over different appliances need to be identified.

The methods to quantify the CVR effects and efficiency are given in [4]. The simulation based quantifying the CVR effects are given in [5] and [6]. In [7], Mathematical static model of electrical load is given to test the CVR effects on it. Local voltage control method for CVR is given in [8]. The local voltage method provides the facility to implement the CVR at consumer premises. Signal processing and control method for CVR is given in [9]. In [10], [11], the CVR implementation method and planning and are given for CVR control at feeder or at substations by utility. Modeling, measurement and verification for a CVR installed substation with real time data is given in [12]. From all the above research and reviews, efficiency of CVR is not tested at consumer premises or with local voltage control method. So in this paper the authors conducted an experiment for measuring the efficiency of the CVR method over commonly using home appliances, the experiment is conducted in machines lab at VIT University, Vellore. A smart plug design is given in [13] to minimize the standby power loss. The modified smart plug design is given in this paper for future implementation of CVR method with in consumer premises. This paper is organized as follows. In Section 2, Description of Experimental setup. In section 3 CVR implementation process with Smart plug. Conclusion is given in section 4.

2. Description of Experimental setup

Power consumption by CVR method is not applicable for all electric home appliances. For this reason, the authors conducted an experiment to test the effects of CVR under different home appliances. The authors used a latest pre-installed digital measuring table in machine lab at VIT University, Vellore is used for this experiment on CVR. The testing table contains digitalized AC power sensor, AC voltage sensor, AC Current sensor, with auto transformer and Digital output. The controllable AC source voltage to the appliances is supplied by an autotransformer. The power sensor is connected between source and load to measure the power. The voltage sensor is connected across the autotransformer to measure the input supply. The testing table with appliance is shown in Fig. 1. To test the benefits of CVR with respect to different home appliances, initially the appliances are supplied with 230v. The power consumption with supply voltage of 230v is measured. Then the same appliances is operated with supply voltage of 200v. And the power consumption for 200v is measured. Same like this the experiment was conducted with some home appliances which is commonly used. Table 1 shows the power consumption of different home appliances with 230v and 200v supply voltage. From the table, the power consumption for most of the home appliances reduced by VRM. Power consumption for PC desktop, TV, Induction Stove, PC monitor and lighting are not changed by VRM. This type of appliances belongs to constant power characteristics. This experiment show the VRM reduces the power consumption for about 64% of electric home appliances. In Fig. 2. Shows the power consumption with respect to time for Induction Stove, Iron, Electric Cooker, and Microwave Oven. In this figure, Induction stove consume 1040w with 200V supply and 1012w with 230v supply. This shows that 2.8% of power consumption is increased with decreasing the supply voltage. So the induction stove is not suitable for CVR method to power consumption.

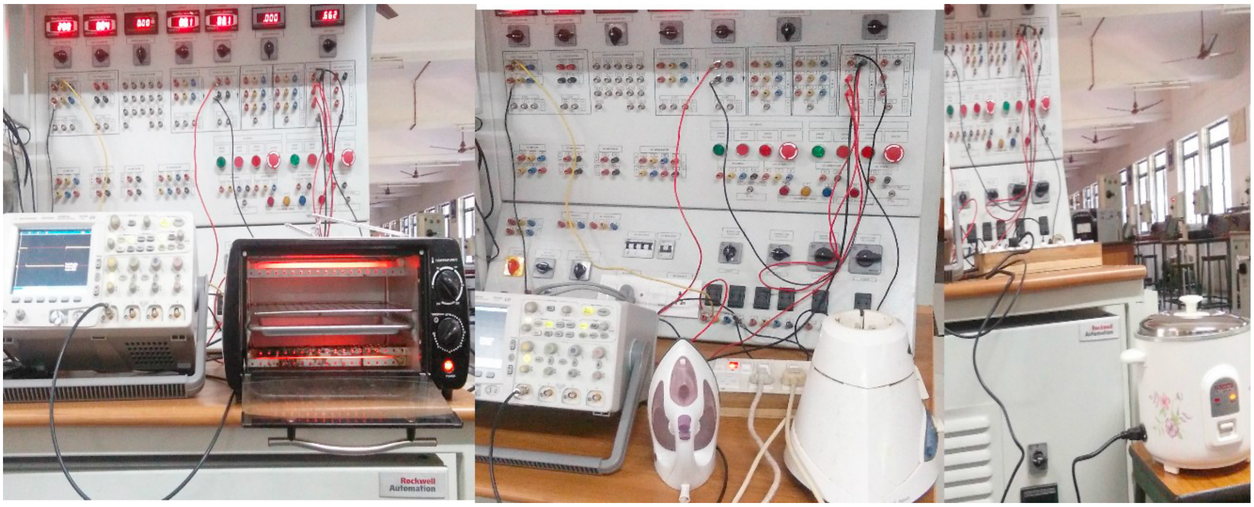

Fig. 1. Experimental setup

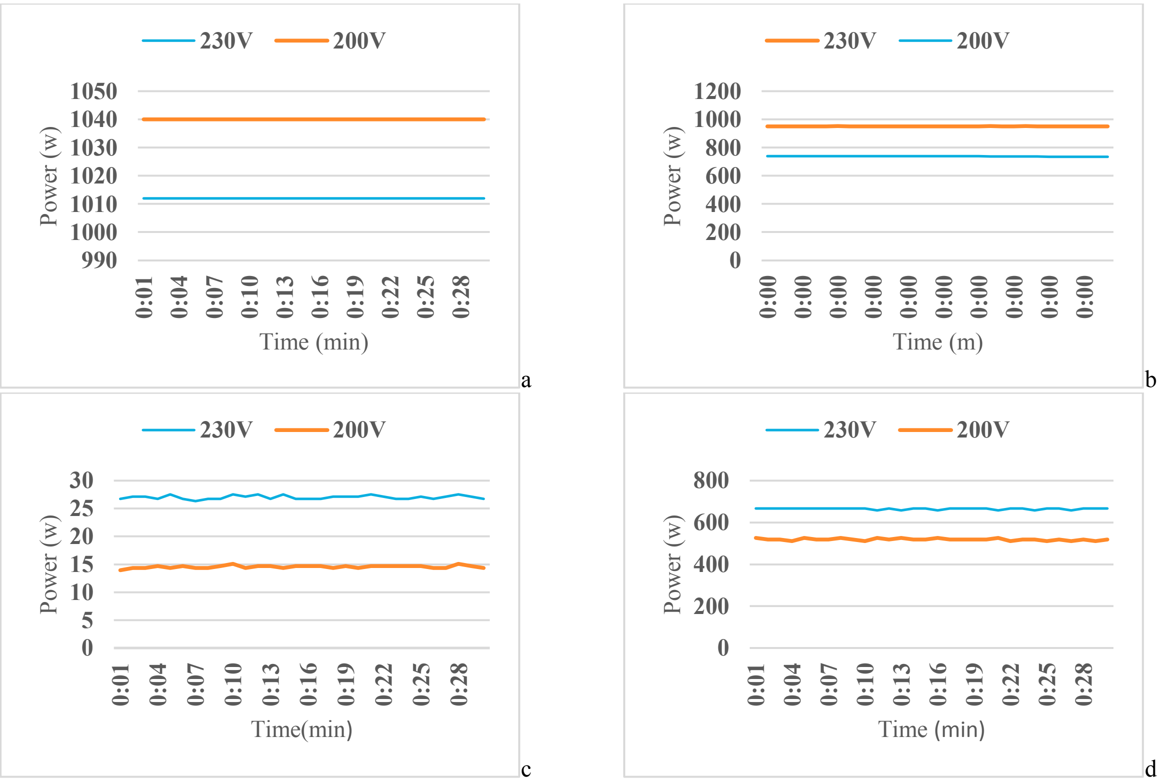

Fig. 2. Appliances Power Consumption, a. Induction Stove, b. Iron, c. Electric Cooker, d. Microwave oven.

Table 1. Experiment result.

Appliances	Measured Power(Watt)		Percentage of power reduced (%)
	For 230V input	For 200V input	
Electric Cooker	609.45	467.13	23.4
Microwave Oven	666.10	526.60	20.9
PC desktop	55.00	55.00	0.0
Kittle	1840.00	1440.00	21.7
Iron	951.09	730.58	23.2
TV	121.83	121.83	0.0
Induction Stove	1012.00	1040.00	-2.8
PC monitor	17.00	17.00	0.0
Water Heater	1061.36	922.92	13.0
AC	800.00	635.16	20.6
Washing Machine	400.00	347.82	13.0
Fridge	109.00	94.78	13.0
Lighting	240.00	240.00	0.0
Table fan	30.60	22.85	25.3
Water pump	371.99	323.47	13.0
Mixer Grinder	296.23	238.00	19.7

3. CVR implementation process with Smart plug

To simplify the implementation of CVR with in consumer place, a simple and low cost CVR smart plug is proposed in this paper. Centralized voltage control with in a home can be achieved in this proposed smart plug. This smart plug is designed with aim to reduce peak demand and reduce power consumption. When CVR is implemented at peak hours, then the peak demand will reduced. So the smart plug in connected with central control system wirelessly to enable and disable CVR with respect to time. The block diagram of implementation of CVR smart plug is shown in Fig. 3. In this figure, the AC voltage from the grid is connected with a smart meter to measure the overall power consumption of the home. Then the appliances is connected with smart plug. Supply voltage from the grid to appliances is supplied via smart plug. So smart plug have full control to supply the voltage to appliances. The block diagram of smart plug is given in Fig. 4. From the figure the AC voltage can be tapped with two different voltage magnitude level. One is AC magnitude without transformer to get voltage output of 230v and another one is voltage magnitude reduction from 230v to 200v using stepdown transformer to get voltage output of 200v. The tapping of voltage magnitude is achieved by two solid state relays. The control signal for solid state relays is given from a ZigBee module. The control signal to ZigBee module is received from central control system. So central control system can able to control the voltage magnitude of all appliances, which is connected to smart plug. Control system contains a microcontroller and a ZigBee module. So in future, when peak hour's data is uploaded to the central control system microcontroller, then the central control system will enable the CVR method to all appliances during peak hours and disable the CVR method during off peak hours. Due to smart plug the CVR can be implemented only with constant current and constant resistant appliances.

To test the efficiency of CVR for its energy consumption level, an experimental test is done with Induction Stove, Iron, Electric Cocker, Microwave oven, Mixer Grinder, and Kittle. This experiment was conducted for 2 days. For first 24 hours (day 1) the appliances supplied with 230v. And for second 24 hours (day 2) the appliances supplied with 200v. The time and duration for turn-on and turn-off for day 1 and day 2 are same for all appliances. The power consumption of appliances with 230v respect to time is shown in the Fig. 5. The power consumption of appliances with 200v respect to time is shown in the Fig. 6. The result shows that the energy consumption on day 1 is 2.864kWh and energy consumption on day 2 is 2.43kWh. Around 15.154% of energy is saved on day 2 while comparing to day 1.

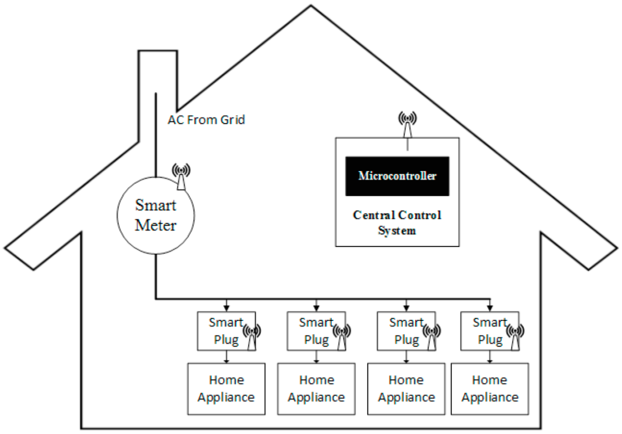

Fig. 3. Block diagram of CVR smart plug

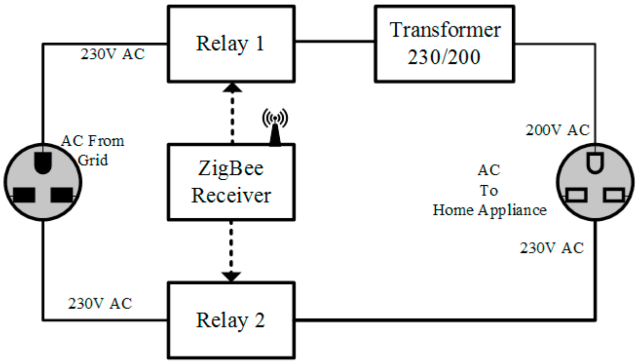

Fig. 4. Smart Plug block diagram

4. Conclusion

An experiment was conducted for testing the benefits of CVR with commonly used electric home appliances, and the results shows that power consumption of around 64% of home appliances are reduced with CVR. The results shows that CVR for induction stove is not suitable. This result helps to modify future implementation of CVR to achieve optimal power savings from CVR. A new low cost smart plug design is given in this paper to implement the CVR on consumer premises. To test the energy consumption efficiency of CVR method, an experiment was conducted for 2 days on using electric home appliances. Day 1 without CVR and Day 2 with CVR. The results shows CVR method saves around 15.15% of energy consumption on comparing with Day 1. So it can be concluded that, CVR is an efficient method for reducing the power consumption and to reducing the peak demand. But the very important limitation of CVR method is, choosing suitable electric appliances for implementation. This paper is a part of main research work of the authors. The future scope of this work can be developing smart plug and central control system by including optimization algorithm for reducing the peak demand without sacrificing customer comfort level.

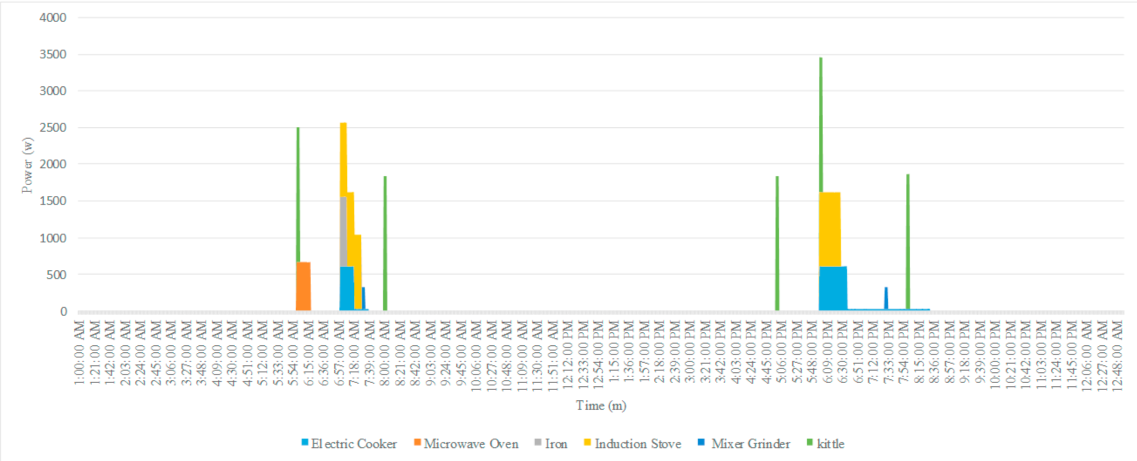

Fig. 5. A day power consumption profile with 230v supply voltage

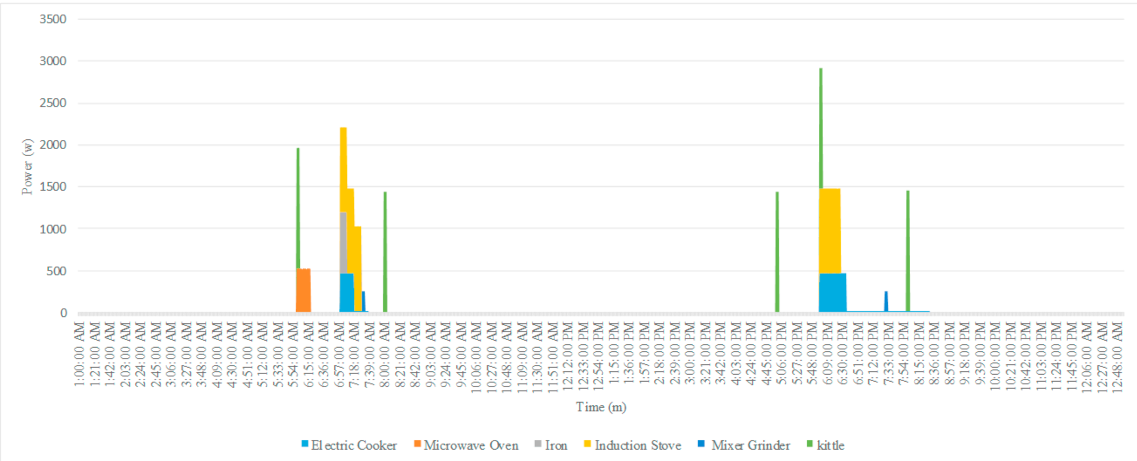

Fig. 6. A day power consumption profile with 200v supply voltage

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