NOVATEUR PUBLICATIONS
INTERNATIONAL JOURNAL OF INNOVATIONS IN ENGINEERING RESEARCH AND TECHNOLOGY [IJIERT]
ISSN: 2394-3696
VOLUME 6, ISSUE 5, May-2019

MODELING AND SIMULATION OF IMPROVED ENERGY MANAGEMENT SYSTEM

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ABSTRACT
This paper demonstrates the functionality of a power electronics based energy management system (EMS). The EMS includes batteries and a digitally controlled single phase voltage source inverter (VSI) which can be controlled as a current source or a voltage source depending on the status of the AC grid and the user's preference. The EMS guarantees that the critical loads are powered when the AC grid fails; in which case the VSI is controlled as a voltage source. It also accomplishes peak power control by supplying battery power to the local loads while they are powered by the AC grid if the loads get large. The electricity cost savings accomplished by peak shaving are estimated

INDEX TERMS: energy management system (EMS). voltage source inverter (VSI), peak shaving

I INTRODUCTION
An energy management system (EMS) is a system of electric utility grids to monitor, control, and optimize the performance of the generation and/or transmission system. Energy management systems are also often commonly used by individual commercial entities to monitor, measure, and control their electrical building loads. Energy management systems can be used to centrally control devices like HVAC units and lighting systems across multiple locations, such as retail, grocery and restaurant sites. Energy management systems can also provide metering, sub metering, and monitoring functions that allow facility and building managers to gather data and insight that allows them to make more informed decisions about energy activities across their sites.
Energy management is the key to saving energy in your organization. Much of the importance of energy saving systems from the global need to save energy - this global need affects energy prices, emissions targets, all of which lead to several compelling reasons why you should save energy at your organization specifically. Energy management is the means to controlling and reducing your organization's energy consumption. And controlling and reducing your organization's energy consumption is important globally we need to save energy in order to (I) Reduce the damage that we're doing to our planet, Earth. As a human race we would probably find things rather difficult without the Earth, so it makes good sense to try to make it last. (ii)Reduce our dependence on the fossil fuels that are becoming increasingly limited in supply.

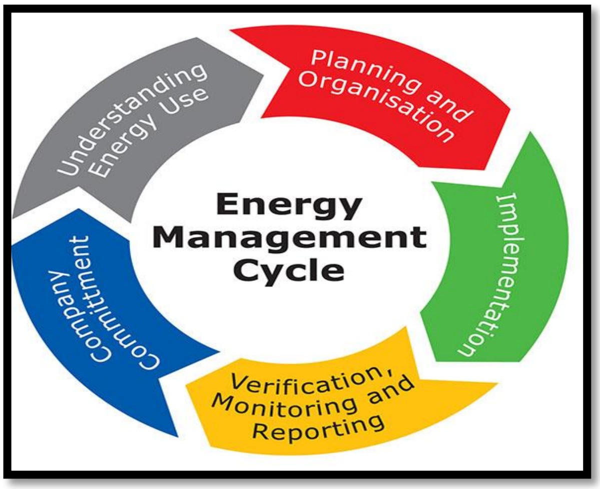

Fig 1 Energy Management system

Energy savings and energy efficiency have become top priorities all around the world, stimulated by the Kyoto protocol and other pressing needs to reduce fossil fuel consumption. Additionally, energy security is a necessity for many installations such as military bases and health care facilities where reducing energy consumption must be accomplished while keeping critical electrical loads serviced at all times. In this project a power electronics based energy management systems (EMS) is presented to accomplish peak power control in a single phase power system while guaranteeing continuous service to critical loads at the same time. Peak power control, also known as peak shaving, is a method used to reduce the electricity charges for users with time of use (TOU) contracts and those who pay for the demand charges.

II EXISTING AND PROPOSED CONFIGURATION

Implementation of an energy management system (EMS) is useful to identify energy saving opportunities and reap long term benefits. An EMS involves a systematic process for continually improving energy performance and maximising energy savings.[9] depending on the current level of operational practices, an EMS also often has the potential to achieve considerable energy savings through operational change alone rather than through capital intensive technology changes. However, in companies without a clear energy strategy in place, opportunities for energy efficiency improvement may be known but not promoted or implemented because of a variety of barriers, including senior management commitments, low energy prices, limited knowledge of the topic, limited finances, among others.[11]

Electrical energy is easy to use and is flexible for various applications, including energy conversion. Batteries are devices which can store and discharge energy, and are used in many areas. From among such uses, this section outlines three that are attracting attention in the areas of industry and infrastructure. These are: the power peak shift, which shifts the peak time at which the most electricity is consumed; business continuity planning (BCP), which is important after a disaster; and ancillary service, which aims at stabilizing power grid systems[11]

Table 1 Comparison between Different Existing systems

Paper	Name of paper	Author	Research
IEEE[2012]	Renewable and Efficient Electric Power Systems	G. M. Masters	Work on Renewable and Efficient Electric Power Systems
IEEE-[2014]	Control of power converters in AC micro grids.	J. Rocabert, A. Luna, F. Blaabjerg, P. Rodriguez	Work on Control of power converters in AC microgrids.
AIMS[2015]	A review of single-phase grid connected inverters for photovoltaic modules	S. B. Kjaer, J.K. Pedersen, F. Blaabjerg	Work on single-phase grid connected inverters for photovoltaic modules
IEEE[2013]	Review of battery charger topologies, charging power levels, and infrastructure for plug-in electric and hybrid vehicles	M. Yilmaz, P.T. Krein	Work on power levels, and infrastructure for plug-in electric and hybrid vehicles .
IEEE[2010]	Energy Storage Systems for Transport and Grid Applications	S. Vazquez, S. M. Lukic, E. Galvan, L.G. Franquelo, J. M. Carrasco,	Work on Energy Storage Systems for Transport and Grid Applications
IEEE[2014]	Grid-Interfacing converter systems with enhanced voltage quality for micro grid application—Concept and Implementation	F. Wang, J. L. Duarte, M.A.M.Hendrix	Work on Grid-Interfacing converter systems with enhanced voltage quality for micro grid

This project demonstrates the functionality of a power electronics based energy management system (EMS). The EMS includes batteries and a digitally controlled single phase voltage source inverter (VSI) which can be controlled as a current source or a voltage source depending on the status of the AC grid and the user's preference. The EMS guarantees that the critical loads are powered when the AC grid fails; in which case the VSI is controlled as a voltage source.

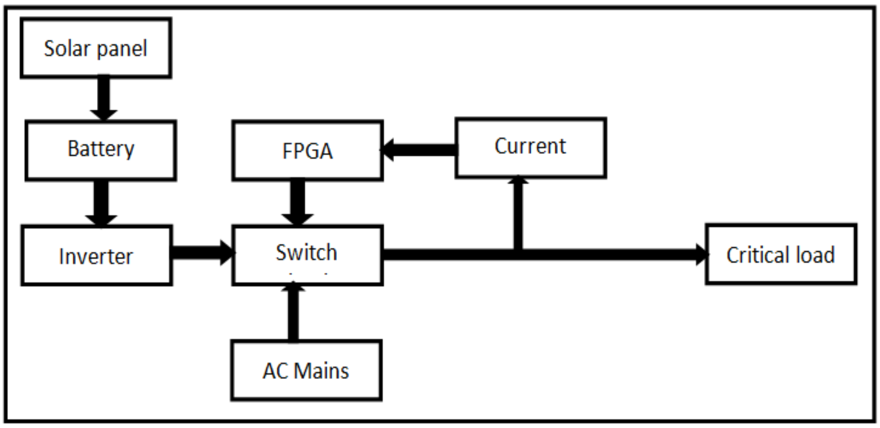

Fig 2 Proposed System Overview

The major objectives of proposed system are to design an EMS which includes batteries and a digitally controlled single phase voltage source inverter (VSI) . It can be controlled as a current source ora voltage source depending on the status of the AC grid and the user's preference. The EMS guarantees that the critical loads are powered when the AC grid fails; in which case the VSI is controlled as a voltage source. It accomplishes peak power control by supplying battery power to the local loads while they are powered byte AC grid if the loads get large.

The system describes the design and operation of energy management system includes batteries and a digitally controlled single phase voltage source inverter (VSI).The EMS guarantees that the critical loads are powered when the AC grid fails; in which case the VSI is controlled as a voltage source. It accomplishes peak power control by supplying battery power to the local loads while they are powered by the AC grid if the loads get large.

III EXPERIMENTAL VALIDATION

The circuit shown was built in the laboratory to demonstrate the EMS functionality. The AC voltage is vac=120Vrms, the battery pack voltage is vbatt=72Vdc and it is boosted to create the DC bus voltage vdc= 200 V for the H-bridge inverter. The EMS output filter includes a 12□F capacitor and 1.16 mH inductance distributed on both sides of the capacitor. The loads include a diode rectifier and RL loads as shown in Figure 8. The passive components can be adjusted to create different load conditions. The objective of this section is to demonstrate the modes of operation of the EMS with load step changes.

Peak Shaving and Battery Charging with the AC Grid Connected

Residential and commercial time of use (TOU) electricity rates include different rates at different time of the day (such as on-peak and off-peak) and also demand charges. Demand charges are based on the customer's peak demand on a given month, usually averaged over a 15-minute period. TOU rates are devised by the power companies to encourage customer to shift their loads away from the peak demand times and in general reduce their peak power consumption. The ideal customer would draw constant power at all hours of the day. Reducing the peak power consumption results in significant cost savings. Peak shaving is a known technique used to achieve this objective by use of stored energy. Electrical energy is stored during the times when electricity cost is lowest (typically at night) and used during the times when electricity cost is highest, in order to reduce the overall electricity charges. While it may not be cost effective to acquire a battery pack with the sole purpose of peak shaving, if storage is part of an existing EMS installed to improve the reliability of the local power system, then using it to accomplish peak shaving is very cost effective as will be demonstrated in section VI. Peak shaving is achieved by controlling the RMS current in the load, which is related to the source current. A threshold is set for the load current such that when the load RMS current exceeds this threshold the EMS supplies some of the load current. This keeps the peak current drawn from the AC grid below a set limit. In the laboratory experiments presented here, the threshold for the load current is such that the peak shaving feature turns on when the load current is greater than 2.2 Arms and turns off when the load current is below 2.1 Arms. When peak shaving turns on the EMS behaves as a current source supplying to the load a sinusoidal current with unity power factor.

The threshold value can be changed by modifying the EMS reference current by the secondary controller. The EMS can be programmed to provide reactive power as well as current harmonics as needed by the user or the secondary controller. In this paper however only active power control is demonstrated. Figure3 include the experimental waveforms obtained in AC grid connected mode. Table I displays the values of the different loads used to create the waveforms in these figures. In and Figure the turn on of the EMS is demonstrated. The load current increases and the EMS current supplies some of the current to reduce the peak power consumption from the grid. A step change in the load is implemented by changing “Load 2” in Figure 3 and Figure4. The only difference between the two sets of waveforms is that the diode rectifier is included in the load in Figure4 while it is not part of the load in Figure 3. The diode rectifier is excluded from the circuit by making the variable resistor labeled as “Load 1” very large, indicated as ∞. It can be noted that the non-linear load has a significant effect on the quality of the current waveforms but it doesn’t change the dynamic of the EMS turn on event. At this time the EMS cannot compensate for the load current harmonics, future work will add this capability so that the source current can be made sinusoidal with non linear loads.

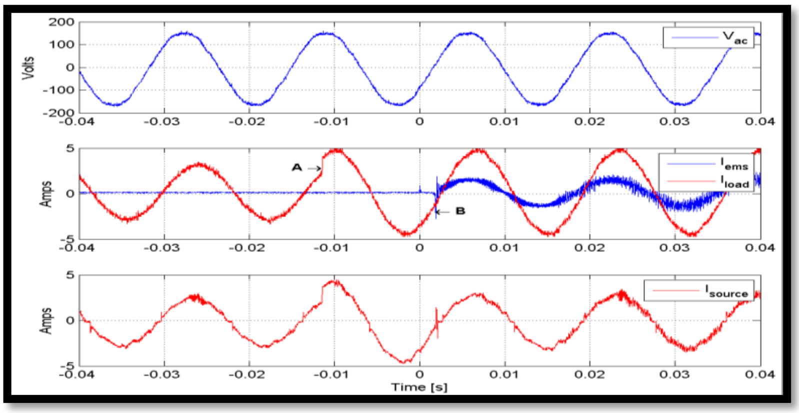

Fig 3 Peak shaving with the EMS providing some of the load current from the battery pack when the load increases. Load 2 steps from 600 to 80 and then the EMS turns on (B). All the loads are linear.

The EMS turns on to charge the battery at t=0 seconds in Figure 5 as demonstrated by the EMS current Iems being 180 out of phase with respect to the AC voltage. As can be noted from Table I, only linear loads are used for this experiment, because the diode rectifier load is disabled. The battery charging mode of operation is allowed because the load is light, so the EMS does not need to provide additional current for peak shaving. A secondary controller typically turns on the battery charger when the cost of electricity is lowest and the loads are light, which happens a night in most cases.

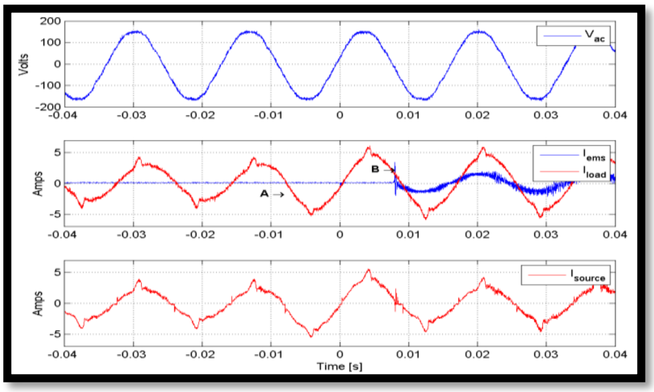

Fig 4. Peak shaving with the EMS providing some of the load current from the battery pack when the load increases. Load 2 steps from 1200 to 85.7 and then the EMS turns on (B). The load includes a diode rectifier.

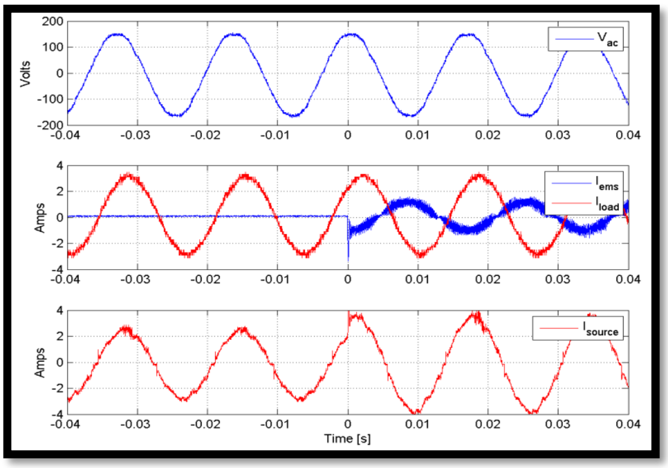

Fig 5. EMS turning on at t=0 to charge the battery pack.

There is a delay between the load increase and the EMS turning on due to the RMS current computation algorithm, which is described in the next subsection.

EMS Powering Critical Loads when the AC Grid Fails – Islanding Mode of Operation

In order to provide power to critical loads when the AC grid fails, the EMS detects grid failure and acts as a voltage source for the critical loads. In this mode of operation non critical loads can be shed depending on the state of charge of the batteries and other factors determined by the user or by the secondary control system. Non critical load shedding is easily accomplished by the EMS by opening the thyristor switch connected to the non-critical loads. When the AC grid is available again, then the EMS restores the loads to the AC grid, therefore terminating the islanding mode of operation. At this point, if non critical loads had been previously disconnected they can be restored as determined by the secondary control system. The secondary control system determines if the EMS should try to reconnect to the AC grid or not.

The experimental waveforms in Figure 6 through Figure 7 show how the EMS enters and exits the islanding mode of operation. In grid connected mode the EMS is always monitoring the phase angle of the AC source. When the RMS voltage falls below a set threshold (100V) the EMS interprets the event as a grid failure and switches to islanding mode of operation. The load conditions for the experimental set up used to obtain the waveforms in the three figures. Grid failure with EMS turning on is demonstrated in Figure6 and Figure 7 with two different corner frequencies for the low pass filter of the RMS voltage monitoring system show. Increased frequency results in faster transient response.

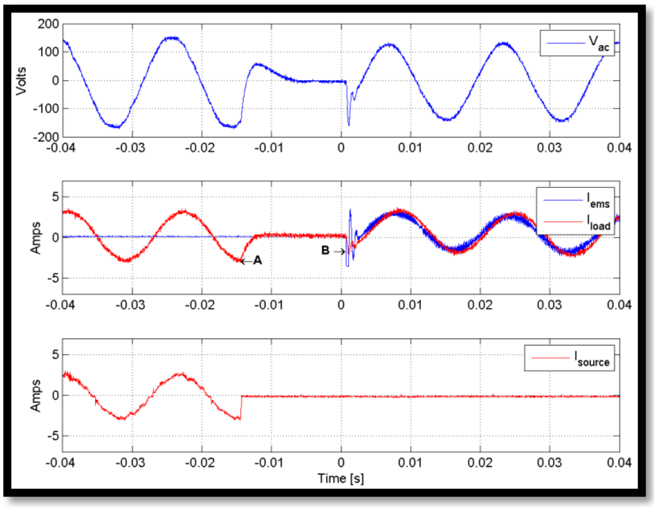

Fig 6. Experimental waveforms showing AC grid failure (A) and the EMS taking the loads into islanding mode (B).

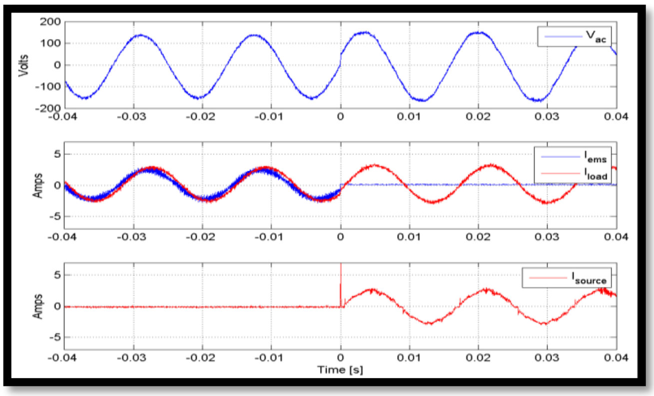

Fig 7. Experimental waveforms showing the AC grid being restored at t=0

The return to AC grid connected mode is demonstrated in Figure7. The difference between the marked points 'A' and 'B' in Figure 6 and Figure 8 shows the impact that the low pass filter corner frequency a has on the dynamic response of the EMS to grid failure. The loss of source delay (B-A) is 15.1 ms in Figure 4.and 5.7 ms in Figure 15. Clearly the fast response is preferred for a smoother transition from grid-connect to islanding mode of operation. However the drawback of a fast response time is that is landing mode could occur even if there is no loss of power, but simply a voltage notch. Of course, this could be desirable depending on the sensitivity of the loads being serviced.

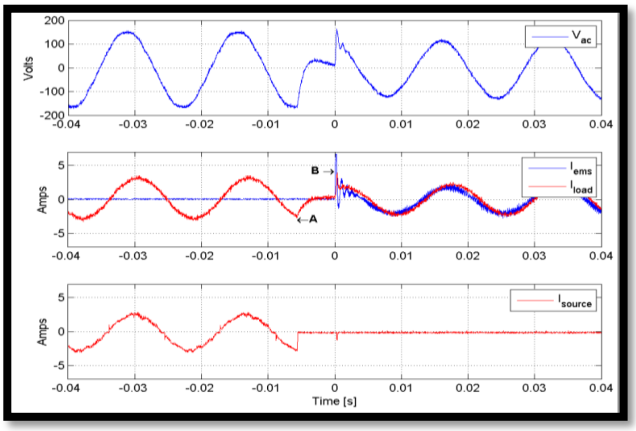

Fig 8. Experimental waveforms showing AC grid failure (A) and the EMS taking the loads into islanding mode (B).

The disturbance in the voltage waveform is noticeable when the EMS reconnects the AC grid to the loads as shown in Figure7.The disturbance in the voltage waveform is noticeable when the EMS reconnects the AC grid to the loads as shown in Figure7.

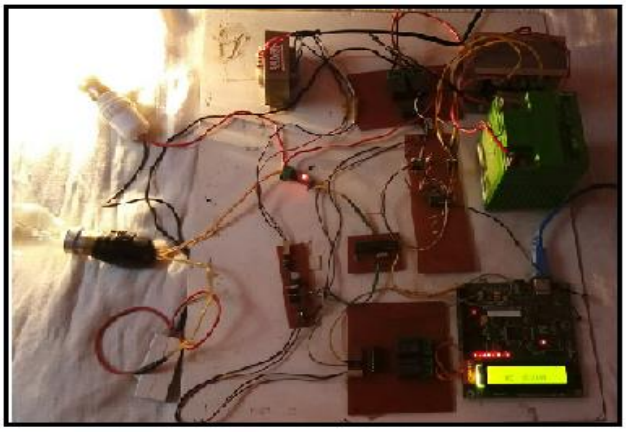

Fig 9 Mains ON

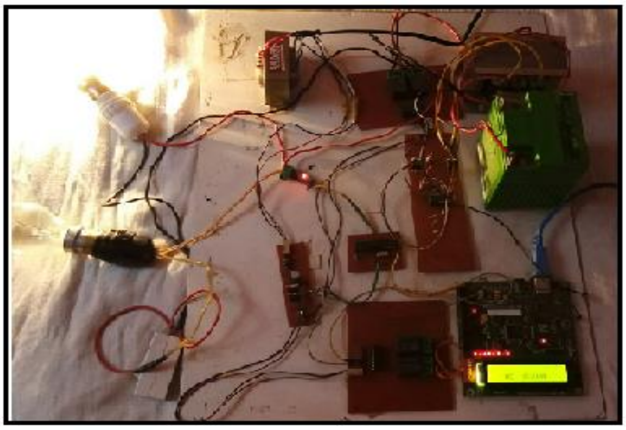

Fig 10 Inverter ON

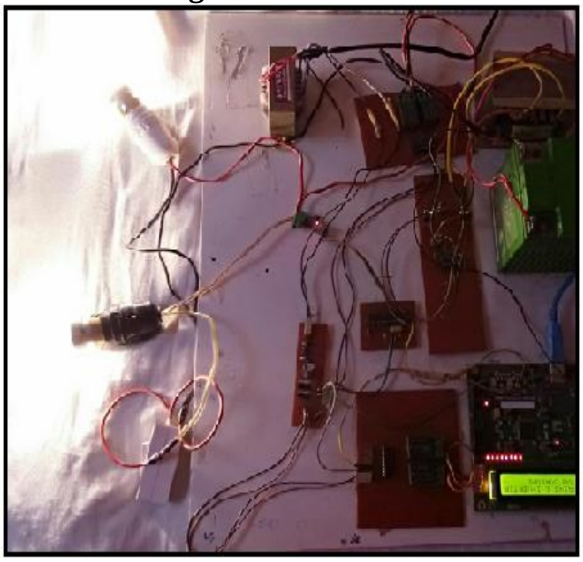

Fig 11 Mains ON and Inverter ON

An EMS can be embedded in a building's power system to guarantee continuous service to critical loads when the AC grid is down. In addition the EMS can reduce the cost of electricity by Implementing peak shaving .The concept is simple and well known .It involves storing electrical energy when the cost of energy is low and utilizing the stored energy when the cost of energy is high. An additional benefit is that demand charges, which are based on maximum load during the peak demand period, can be reduced as well. The energy stored can come from the AC grid during off peak hours or from DG such as photovoltaic arrays, fuel cells, gas generators or wind turbines, as examples

It is known to almost all of us that the energy sector of a country has great impacts on the growth and development of the country. The availability of different resources of energy and the proper use of the resources for the progress of any country, serves as the key factor towards the economic growth and development of the nation. To reduce operating costs and cut wastage, manufacturers must take their energy management optimization efforts beyond utility consumption monitoring and focus on the total work stream: building infrastructure, supply chains, product design, transportation, plant equipment and controls and smart metering.

CONCLUSION

In this project the functionality of a power electronics based EMS is demonstrated with a laboratory prototype. The control system designed to perform the experimental implementation of typical scenarios is presented in detail. Experimental data is shown to demonstrate how the EMS supports critical loads when the AC grid becomes unavailable and how the connection to the AC grid is restored by the EMS when the AC grid becomes available again. Additionally, the EMS can accomplish other advantageous tasks such as peak shaving. Experimental measurements with linear and non-linear loads demonstrate how the EMS, controlled in current mode, provides some of the power to the loads to accomplish peak shaving, thus reducing the cost of electricity. A simple economic analysis is provided in support of this statement.

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