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A Strategy to Reduce Grid Stress through Priority-based Inverter Charging

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Abstract

Many developing countries face electricity supply shortfall. Utility operators induce scheduled power cuts to keep the demand under the available electricity supply. To deal with power cuts many consumers use inverters and fossil fuel generators. Inverters charge from the same electricity distribution system and provide energy to essential loads during power cut hours. However, uncontrolled use of inverters has created a cyclic load problem for an already stressed grid. In this paper, we propose a scheduling strategy that charge the inverters according to time of use pricing and consumer specified criteria of retaining minimum and maximum levels of charge in the battery. This strategy not only is able to lower the grid stress to a level specified by the grid operator but is also able to reduce the cost of ownership of inverters by as much as 30%. Additionally, this strategy has also shown to reduce the usage of fossil fuel generators due to availability of extra electricity in the system.

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1. Introduction

Electricity Deficits are prevalent in many developing countries. For instance in Pakistan the electricity shortage has been a major issue since the last decade. The Peak Demand is around 23 GW, while the power generation capability is 18 GW [1]. Thus the power deficit in 2015-16 is around 5 GW. To meet this gap the utility companies are forced to induce power cuts ranging from 3 hours to 12 hours in a day with an average of 5.3 hours load shedding per day. Typically these power cut hours are announced in advance in hourly slots spread throughout the day.

Most power cuts are scheduled in the peak hours to meet the electricity deficit. To reduce the effects of power cuts on everyday lives, a large number of consumers use back-up power to run their essential electrical loads. According to estimates around 28% of the people use battery based inverter backups while a good number also use fossil fuel generators [2]. The exhaust from fossil fuel generators contain more than forty air pollutants[3]. Fossil fuel generators have no direct impact on utility companies as they consume fossil fuels as a source of energy. Although the focus of this paper is reducing the inverter load on the grid but at a later stage in the paper we will show how reducing the stress on the grid may also help in reducing fossil fuel generators usage.

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Inverters are designed such that they charge their batteries when the electricity is available from the utility companies. During the power cut hour, the charge in the batteries provide electricity for essential loads. Following a power cut hour inverters start charging their batteries. There are two major problems with this approach. The first one being the sudden peak load caused when all the inverters start charging their batteries together. Assuming the penetration level of 28% there would be hundreds of thousands of inverters charging at any given moment, causing significant peak load on the grid. The demand puts considerable stress on the grid, thus increasing the risk of further blackouts and increasing the cost of generation of electricity. The second major problem is the effect on the consumers which include variation in cost of charging the inverter battery, life of the backup battery and the inconvenience caused to the consumer due to unconstrained charging.

Furthermore, inverters are big time electricity wasters as well; the inversion, storage and rectification losses of charging a typical inverter sum up to be around 75% percent [4] [5]. These losses add to increase the electricity cost for the consumer as well as more stress for the grid.

The rest of the paper is structured as follows: Section 2 provides the Related Work. Section 3 analyzes the impact of unscheduled inverter charging. Section 4 discusses our proposed Inverter Charging Strategy. Section 5 shows the evaluation of our approach and finally Section 6 concludes with a discussion and future directions.

2. Background and Related Work

Alonso et al. discussed the hidden cost of inverters and battery backups [4]. In their paper they calculated energy losses incurred due to inverters and the impact of inverters on grid stability. Our work is different from them because we are more focused on the cost based analysis and effective scheduling to reduce the peak loads on the grid.

Another related work in EV (Electric Vehicles) charging is the heuristics based algorithm for charging of electric vehicles [6]. In this paper the authors have discussed the dumb charging strategy and their strategy based on genetic algorithm which produces significantly better results. However, inverters and EV differ fundamentally based on the availability factor and the fact that EVs are used as supplementary sources of storing additional electricity. But inverters are being used as primary backups of essential loads and they have to be charged at user defined minimum level before a power cut. The concept has been introduced in EV [7] where a minimum SOC has to be maintained in the EV for the daily operational readiness which is also implemented in our work, but unlike EV the inverters have a fixed schedule and they are always connected to the power sources which is different work from EV which is mobile and may be disconnected at random from the power sources.

A cost based approach to measure the effects and cost of power cuts was presented in which a methodology for the quantification of the power outages has been developed in another paper [2]. The work is focused over the total outage cost to residential consumers and they have made policy recommendations to end power cuts for better. It is the only survey of it's kind and differs from our work significantly as we are focusing over optimal charging schedules so that the benefits could be reaped by the electricity supplier as well as the consumers. For electric vehicle charging one purposed solution was off peak domestic charging, in which a simple timed controller is added to the charging circuit which schedules charging to start at 1:00 a.m. and remains on until 7:00 a.m. It will improve the load curve but there will be no significant impact on the distribution network capacity [8]. Although the overall profile is improved, there is still a peak after midnight and a dip at around 7:00 a.m. Our work is different as we schedule the charging hours according to the demand and cost of electricity per hour. Jain et. al worked on collaborative energy conservation in micro grid [9] and have worked with diesel generators scheduling to reduce diesel cost, but our work is different from them as we are only considering the inverter load on a grid and how to efficiently distribute it for benefiting both the consumers and the producers of electricity.

A Time of Use (TOU) and State of Charge (SOC) strategy discussed for EV [10] also used the approach of shifting the load to an area where the pricing is low and have taken the max battery charge which is user specified but our approach is different because we are utilizing the charging windows to provide the user defined SOC in two categories with different priorities A & B. EV charging strategies based on the distribution level capacities are discussed in another paper by Ahmet Dogan et al.[11] where they have worked on three EV charging strategies based on the load on distribution and with normal and quick charging modes. They have used fixed time based strategies which is different from our strategy, our algorithm optimizes the charging for various charging windows and tries to provide cost based and peak based optimization. Another related work done on PEV charging was done in a published paper

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