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An Energy Based Consumption Alarm Model for Improved Energy Utilization of Power Grids in Smart Cities

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Abstract:

Towards maximizing energy utilization in smart cities, there are number of methods being recommended by the researchers in literature. The scarcity of electricity requires proper utilization of energy and the methods consider the few activities of the consumer in producing alarms. However, the methods are not efficient in finding the overconsumption lines and produces poor performance in energy utilization. To solve this issue, an Energy based Consumption Alarm Model (ECAM) is presented in this paper. The model tracks the behaviors of electric power usage by different consumers and by monitoring their time line in using them, the method identifies the improper usage of electricity and produces alarm to the consumer. To perform this, the method categorizes the devices in consumer line and by analyzing the timeline of usage, the method estimates the Energy Utilization Factor (EUF) for the consumer line and devices. Based on the value of EUF, the method produces alarm to the consumer to restrict the usage of electricity. The proposed method improves the performance of energy utilization and improves the performance of smart grids.

Keywords:

Smart Cities, Energy Utilization, ECAM, EUF, Smart Alarm

Introduction to work:

The human society utilizes the electricity for various works they perform every day. It has been identified as the essential source for the human life. However, the electric power is the highly scarcity one as the source to produce the electricity is limited. In general, the electric power has been produced from solar, thermal, atomic and wind sources. Whatever the source, the power generation organizations suffer to spend huge money on the production of electricity. They also spends huge amount in the installation of the units and for the environment. This increases the requirement of using the electricity for the highly needed one and the utilization of the electricity must be a perfect one.

As the human society spends much electric power for various works, it cannot be restricted from using the electricity but it must be a meaningful one. For example, there are situations where the consumer would consume electricity for unnecessary activities and there are cases where the electric device would be running anonymously. It produces waste of electricity and it must be avoided to improve the utilization. So that, the improper use of electricity should be reduced and avoided.

On the other side, the consumer would consume higher electricity units without knowing the consumption. As the electricity has been billed in various ranges, it is necessary for the consumer to know about the consumption. By providing enough information about the consumption of electricity, the user or the consumer would be aware of restricting the usage. By providing set of alarms and notifications, the consumer can be informed about the use of electricity which in turn would improve the performance of energy utilization. With this consideration, an efficient an Energy based Consumption Alarm Model (ECAM) is presented in this paper. The model tracks the behaviors of electric power usage by different consumers and by monitoring their time line in using them, the method identifies the improper usage of electricity and produces alarm to the consumer. To perform this, the method categorizes the devices in consumer line and by analyzing the timeline of usage, the method estimates the Energy Utilization Factor (EUF) for the consumer line and devices. Based on the value of EUF, the method produces alarm to the consumer to restrict the usage of electricity. The detailed working of the model has been sketched in the next section.

Related works:

There exist number of approaches around the problem of consumer notification and alarms. Such methods are discussed in detail in this section.

A detailed review on the development of resilient power grid in smart city is presented in [1]. The model analyzes various issues in power distribution and presents possible directions for the urban power grid networks. The urban sector would require different power requirement and the models available to handle the problem are analyzed in detail.

A detailed analysis of smart city around its energy need, supply, distribution and management is studied in [2]. The author considered various factors of energy requirement, supply chain available and management problems. Using all these factors, the author recommended an efficient distribution model to support power regulation in smart cities.

A learning surrogate model [JCC-OPF] is presented in [3], which converts joint chance constraints into quantile based forms. The method uses multi-layer perceptron network towards power distribution. The neurons of the network involves in applying various constraints to monitor and measure the power requirement of any area to perform effective power distribution.

Hydrogen refueling service fee (HRSF) based control strategy is presented in [4], to support hydrogen fuel cell electric vehicles (HFCEVs) in selecting the hydrogen refueling stations. The selection of the station is performed according to specific factors like the residual energy.

A multi agent distributed voltage control strategy is presented in [5], which uses proximal Jacobian alternating direction method of multipliers (PJ-ADMM) towards power distribution. The agents are used to collect various data about the residual energy in various units available and based on that the method performs power distribution and altering the direction of the vehicle.

A multi agent reinforcement learning model is presented in [6], towards power distribution in smart cities. The method uses spatial and temporal features in power distribution. The agents are applied to collect various spatial and temporal data from various grid points of the smart cities. Such data are used to measure the requirement of the city and support efficient power distribution.

A cloud assisted Recurrent Neural Network (RNN) and Long Short-Term Memory (LSTM) combined towards the issue of power distribution [7]. The LSTM is used to measure the energy requirement of the cities. Adapting sensor network for the power distribution is presented in [8]. A container driven service architecture is presented in [9], which uses virtual dedicated agent (digital twin) for each user-side smart meter towards effective power distribution. Towards state estimation in multi feeder radial distribution grids, efficient two step approach is presented in [10].

A distributed self-triggered algorithmic solutions is presented in [11], to the frequency restoration control and active power sharing control of islanded microgrids. The self-trigger model analyze the frequency and utilization of electricity and triggers automatically to support power distribution.

An hybrid IMRFO-TS model is presented in [12], which works according to the hybridization of Improved Manta Ray Foraging Optimization (IMRFO) with the Tabu Search (TS) algorithm for solving the UAV placement problem in a smart city. A Dirichlet process mixture model (DPMM) is presented in [13], to handle the uncertainty of load patterns.

All the above discussed approaches suffer to achieve higher performance in energy utilization and regulation.

Methodology:

Energy based Consumption Alarm Model (ECAM):

The proposed energy based consumption alarm model (ECAM) works based on the behavior of the consumer. The model tracks the behaviors of electric power usage by different consumers and by monitoring their time line in using them, the method identifies the improper usage of electricity and produces alarm to the consumer. To perform this, the method categorizes the devices in consumer line and by analyzing the timeline of usage, the method estimates the Energy Utilization Factor (EUF) for the consumer line and devices. Based on the value of EUF, the method produces alarm to the consumer to restrict the usage of electricity.

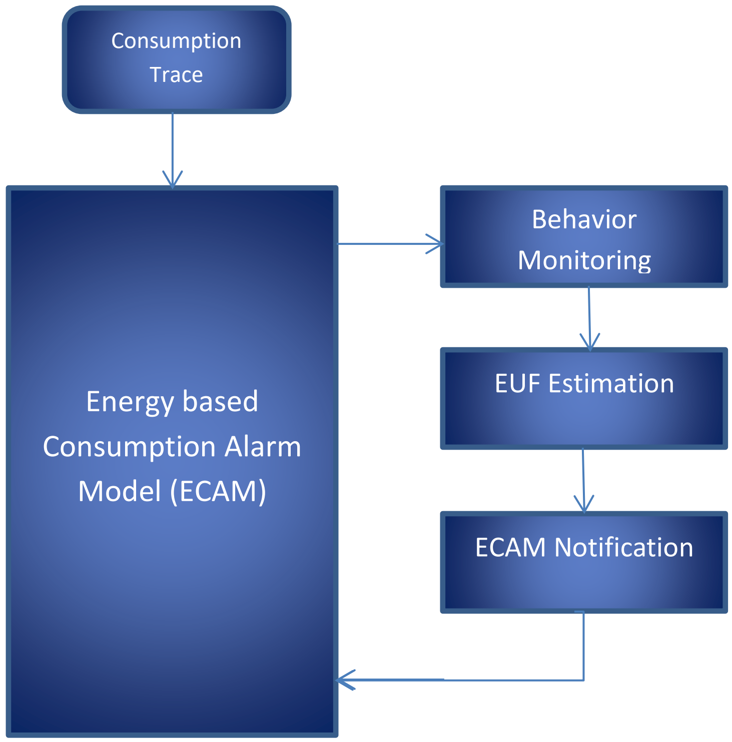

Figure 1: Architecture of ECAM Alarm Model

The architecture of proposed ECAM alarm model has been presented in Figure 1, and the functions of the model is presented in detail in this section.

Behavior Monitoring:

The proposed model monitors the individual connections of the power system. The consumer behavior in electricity consumption has been monitored throughout the day. The user connection has been monitored for the use of electricity. At each time stamp, the average electric usage is measured in terms of EUF (Electric Utilization Factor). According to the value of EUF, the method produces alarm with the ECAM Notification.

Algorithm:

Given: Behavior Trace BT, User Connection Uc
Obtain: Null
Start
Read BT and Uc.

Initialize Fvs.
While true
User Trace UT = $\left(\sum_{i=1}^{size(BT)} BT(i).ConnectionId == Uc\right)$
At each time stamp T
EUF = Perform EUF Estimation (UT)
If EUF>Th then
Perform ECAM Notification.
End
End
Stop

The behavior monitoring function collects the traces of user connection and at each time stamp, the method measure the EUF value and produces alarm accordingly.

EUF Estimation:

The electricity utilization factor is the measure which represents the usage of consumer in consuming the electricity. It has been measured based on the average usage of electricity in various time stamp and current usage value. Estimated EUF has been used to perform ECAM notification.

Algorithm:
Given: User Trace UT.
Obtain: EUF
Start
Read UT..
Compute EUF =

$$\frac{\sum_{i=1}^{size(Ts)} \left(\sum_{j=1}^{size(UT)} Sum(UT(j).Consumption\ ?UT(j).Time==Ts(j)) \middle/ \sum_{j=1}^{size(UT)} Count(UT(j).Time==Ts(j)) \right)}{\sum_{j=1}^{size(UT)} Sum(UT(j).Consumption\ ?UT(j).Time==Current\ Time) \middle/ \sum_{j=1}^{size(UT)} Count(UT(j).Time==Current\ time)}$$

Stop

The proposed approach measure the EUF value for any consumer connection according to the behavior of the user. Estimated value of EUF has been used to produce alarm to the user.

ECAM Notification:

The proposed model monitors the behavior of user in utilizing the electricity. At each time stamp T, the method computes the value of EUF for the user connection. According to the value of EUF, the method produces alarm to the user about the higher usage of electricity.

Results and Discussion:

The proposed Energy based Consumption Alarm Model (ECAM) model has been implemented and evaluated for its performance under various constraints. The results produced by the model have been compared with the result of other methods.

Fact	Value
Tool Used	Matlab
No of connections	2000
Time	24 hours
Number of trace	1 million

Table 1: Experimental setup

The experimental setup considered for the performance evaluation of proposed method is presented in Table 1.

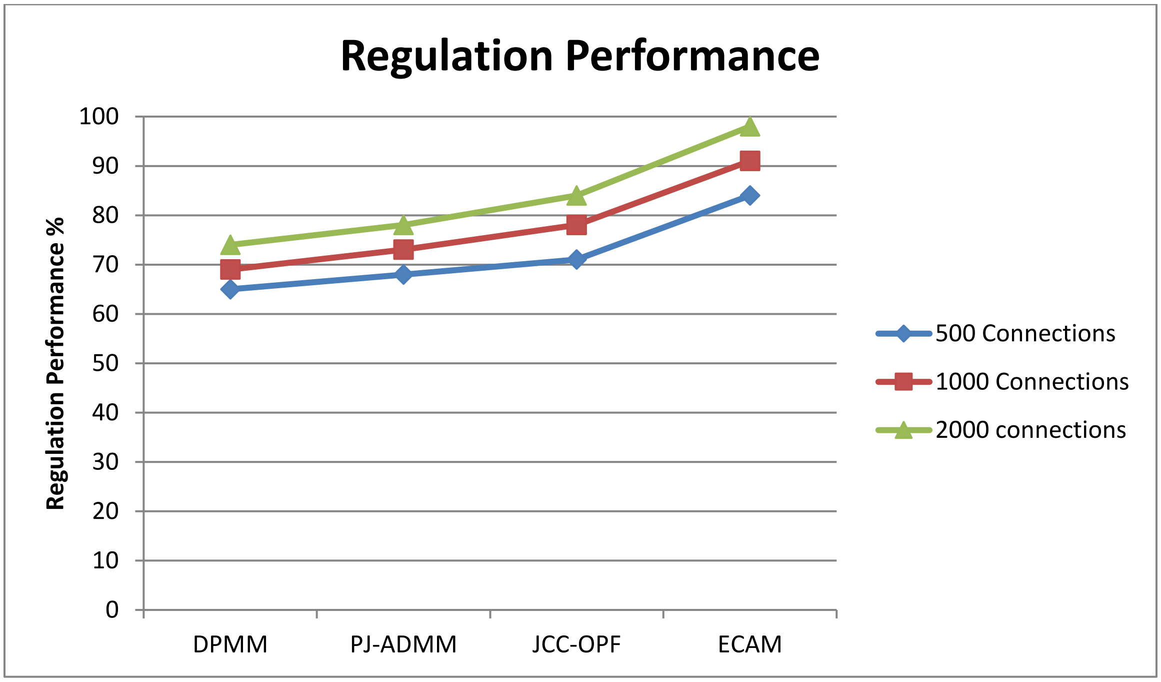

Figure 2: Regulation Performance

The performance in regulation achieved by various models are measured and compared in Figure 2. The proposed ECAM model achieves higher performance than others. The performance of energy regulation is measured according to number of connections. In all the cases, the proposed ECAM model has produced higher performance than others.

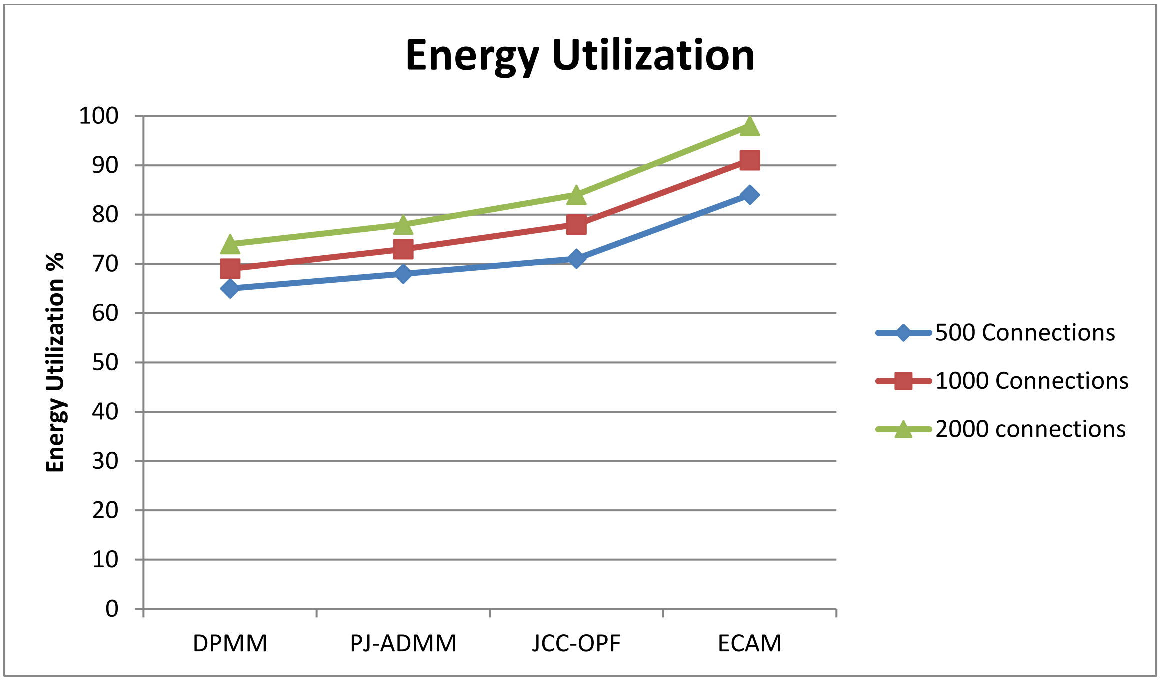

Figure 3: Energy Utilization Performance

The performance in energy utilization has been measured and presented in Figure 3. The proposed ECAM model achieves higher energy utilization than other methods. The energy utilization of methods are measured according to the number of connections in the network. In all the cases, the proposed ECAM model has produced higher performance than other methods.

Conclusion:

This paper presented a novel energy based consumption alarm model (ECAM) works based on the behavior of the consumer. The model tracks the behaviors of electric power usage by different consumers and by monitoring their time line in using them, the method identifies the improper usage of electricity and produces alarm to the consumer. To perform this, the method categorizes the devices in consumer line and by analyzing the timeline of usage, the method estimates the Energy Utilization Factor (EUF) for the consumer line and devices. Based on the value of EUF, the method produces alarm to the consumer to restrict the usage of electricity. The proposed method improves the performance of power regulation and energy utilization.

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