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Demand side management scheme in smart grid with cloud computing approach using stochastic dynamic programming☆

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Summary This paper proposes a cloud computing framework in smart grid environment by creating small integrated energy hub supporting real time computing for handling huge storage of data. A stochastic programming approach model is developed with cloud computing scheme for effective demand side management (DSM) in smart grid. Simulation results are obtained using GUI interface and Gurobi optimizer in Matlab in order to reduce the electricity demand by creating energy networks in a smart hub approach.

Introduction

For the future smart grid era, the need of energy hub builds an intelligent system in electrical pathway. Energy Hub (Chen et al., 2012) is the important consumer outlook face of the Smart Grid, giving in support for the users to reduce the electricity bill and thereby economy. It rather produces intelligent, cost effective tool that fortify the relationship between the users and the utility providers, and also to take care of the vitality issues of today and tomorrow. For the need of creating a vital energy hub as a client server architecture, cloud computing (Palensky and Dietmar, 2011) in smart grid plays a dominant role.

Cloud computing in general is a distributed based internet services (Markovic et al., 2013) where the shared information, resources are provided in a cloud with a connection of data centres, server and clients. As in the concern of bulk data processing, cloud architecture can be used a framework in smart grid (Bera et al., 2015). Further to solve critical issues of user interaction with utility provider, demand side management (DSM) scheme is essential to improve the customer needs and shaping of load for an intelligent grid. Various researches have been carried out for the framework of demand response (DR) modelling with customer satisfaction (Palensky and Dietmar, 2011; Sofana Reka and Ramesh, 2015). The need of improving the DSM scheme is very important without DR congestion. As in shifting the loads from the peak to non peak hours develops a congestion at the non peak hours as the data base of master slave

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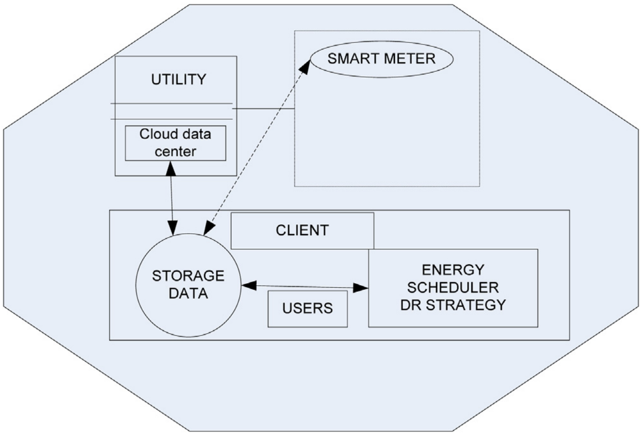

Figure 1 Cloud architecture model with grid interface.

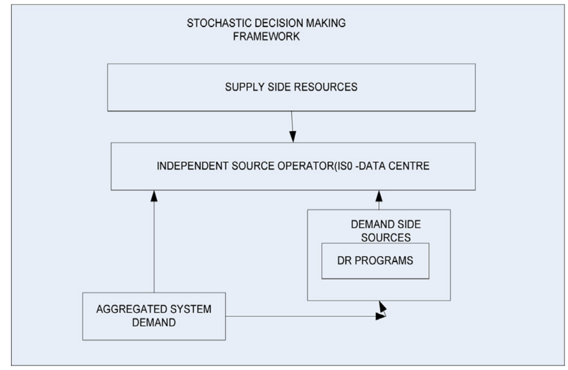

Figure 2 Stochastic model for cloud framework.

architecture should be vital. The communication between the utility and the users should be made easier with the addition of new technology and approaches.

The uniqueness in the proposed approach is that we have described how the system exhibits the consumers to participate in load shifting by DSM programmes by cloud computing approach with complex stochastic model. The methodology structure of the proposed work is we present a cloud base platform with smart grid environment by exploring smart energy hubs using dynamic programming.

Proposed model

The smart energy hub is created in the DSM model by developing energy scheduler considering a set of residential consumers in a locality. This effective model creates efficient DSM programme to shape the aggregated load in a house by developing an energy consumption scheduler. Mathematical approaches using Gurobi optimizer is done for smart energy hubs. In this study the results creates a benchmark with five smart hubs by reducing Peak to average ratio in electricity grid. The proper strategy for each considered hub is done by simulation using dynamic programming. Fig. 1 exhibits the cloud computing architecture in the smart grid paradigm.

Stochastic mathematical model

The modelling of demand response programme with client, server and data centres in cloud computing structure. The two level interactions between the user and the utility provider and the strategy maintained to shape the load in peak hours is done by stochastic process. The data from the clients (users) are stored in a public cloud with smart meter interface (Parvania and Mahmud, 2010). This strategy helps the user to best approach to change the loads and by obtaining incentives from the market provider. The security of data is also modeled with the stochastic decision making framework. Fig. 2 shows the stochastic model of cloud computing approach. DSM develops an interaction between the Energy hubs and the utility. The peak to average ratio (PAR) is to be reduces in order to obtain the maximum profit. The intelligent scheduling of the peak demand shaving is done by stochastic model and the solution is obtained by Monte Carlo method.

Objective function and constraints — model in cloud approach to reduce cost

The objective function derived with a cloud based model of the customer interaction with the utility is stored in a public cloud. The best strategy involved to schedule the residential appliances with a DR model is done in a cloud framework using stochastic dynamic programming. A group of user's energy hubs optimization problem is solved creating an objective function and certain constraints to minimize the cost and maximize the profit for the utility provider.

The energy hubs created with all the users for energy scheduling, the optimization problem is reduced with stochastic dynamic solution by yielding the money profit at the grid side in (1)

$$\max \sum_{k=1}^{T} M_i - M_j \tag{1}$$

$$\min \left\{ \sum_{i \in B} [K(b) = C_x T + (J_{\gamma,i})] \right. \tag{2}$$

Subject to the constraints of payoffs of the energy hubs created and the DR strategy developed with the probability of the all the scheduling strategy $S_N = \sum_{L=1}^{n} s_{kj} (k = 1. \ldots N)$. The variables $C_X T$ exhibits the cost function and the cloud strategy of scheduling vector in energy hub is assigned as $J_{\gamma,i}$. The peak to average ratio of the each user strategy which is moved on the cloud server energy hub is given as $P = \frac{\max \sum_{k=1}^{N} \sum_{i=1}^{24} J_{\gamma,i}(t)}{\sum_{i=1}^{24} S_i(t)/24}$. As per the stochastic model created with payoffs for users, as the load strategy are able to inbuilt in DR scheme with developing cloud server data centre successfully.

Results and discussions

The unique idea of using cloud computing platform for reducing cost is provided with valid computational simulation results. In this process of stochastic optimization with cloud data centres behaving as a public cloud, we have considered for our study with $E = 5$, of energy hubs that are been linked with a utility provider for a set of residential

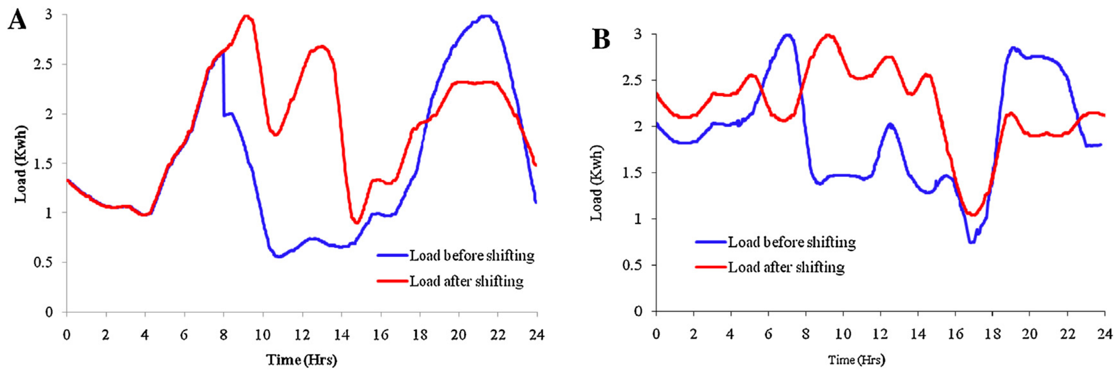

Figure 3 (A) Load shifting before and after DR, (B) energy prices reduction.

Table 1 Cost and PAR reduction with and without DR strategy.

Users	No of energy hubs	Cost reduction		PAR (%)
		Without DR	With DR	
User 1	2	245	232	5
User 2	6	235	200	2
User 3	8	276	252	3

users. The users set up with energy hubs with stochastic energy scheduling done. The scheduling with all the residential appliances with day of time slot of 24 h with 100 kWh. The framework of DSM is been simulated in GAMS solver with the optimization objective solution created. Table 1 shows the list of energy hubs with the users set of configuration with the utility provider.

When the DR strategy is used, all the energy hubs participate in the scheme for reduction of bill. It implies that the peak hours 6.00 to 9.00 pm, there is a decrease in the electricity input consumption. From the cloud computing framework there is reduction in price nearly about 10% in the peak hours, Fig. 3. A shows the electricity cost reduction comparison with and without DR model. Fig. 3B exhibits the energy prices in a day hours schedule with the Energy Hub.

Conclusion

In this proposed work, we have proposed cloud computing framework for DSM in smart grid by creating small energy hub with the users. The consumers were able the shift the load with the use of their own strategy model by creating a stochastic model. The simulation results of stochastic solution of shifting peak hour load are done by Monte Carlo methods. The reduction of PAR and the cost is done with addition to the daily charges of the energy hub in the model.

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