



Dynamic load-shifting program based on a cloud computing framework to support the integration of renewable energy sources



T. Rajeev^{a,*}, S. Ashok^b

^a College of Engineering, Trivandrum, Kerala, India

^b NIT, Calicut, Kerala, India

HIGHLIGHTS

- Dynamic load-shifting method increases self-consumption of renewable energy and lowers peak load.
- Cloud computing based solution to address the big-data issue in the implementation of a DSM program.
- Multi-agent approach facilitate coupling of load-shifting operations with dynamic pricing in a single framework.
- An optimisation method is presented to minimize excess electricity injection into the grid from solar PV system.

ARTICLE INFO

Article history:

Received 12 June 2014

Received in revised form 14 January 2015

Accepted 7 February 2015

Keywords:

Intermittent resources

Dynamic renewable factor

Solar rooftop PV

Cloud computing

ABSTRACT

Demand-side management programs such as load shifting utilise the flexibility in the load consumption pattern of consumers to enable the effective capacity utilisation of renewable energy sources. The locational and temporal characteristics of renewable energy sources cause forecasting and operational challenges in the implementation of such a renewable energy program. In this paper, a dynamic load-shifting program using real-time data in a cloud computing framework is proposed to address the aforementioned issues. A new dynamic renewable factor is proposed to facilitate on-time incentive based load shifting program. The effectiveness of the dynamic load-shifting program was evaluated using simulated case studies. The case study indicates that PV energy utilisation at the consumer side is increased by 18% by the application of the proposed load-shifting program. The study result in Kerala, India, consisting of more than 7.5 million domestic consumers, indicates that demand reduction of 250–300 MW at times of peak demand can be achieved by using load shifting in the domestic sector.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

Electric power generation using consumer-owned grid-connected solar photo voltaic and wind generators is increasing at the distribution level. The intermittent and site dependent characteristics of renewable energy sources that result in uncertainty in the generation result in reliability and stability problems in the distribution system. Demand side management (DSM) programs for efficient utilisation of renewable energy on the consumer side are considered as one of the solutions to reduce the adverse impact of renewable energy sources on the grid [1,2]. The uncertainty is a challenge in the design and operation of electrical systems that include renewable energy generation. Since electricity demand and the availability of output from renewable energy sources are

intermittent by nature, system operators have to use advanced forecasting methods such as artificial neural networks (ANN) to support demand side management programs [3,4]. Additionally, the high level penetration of renewable energy sources in the domestic sector brings new operational challenges of handling and processing a huge amount of time series data at the household and utility level in the implementation of a DSM program.

Load shifting is applied upon demands to achieve a better match with the time-varying supply from renewable energy sources. The existing methods for load shifting, which follow centralised coordination and processing, are mainly based on the capacity of generation and demand forecasted over a given time period. The integration of renewable sources brings new operational challenges to the existing methods. The increasing share of renewable energy with fluctuating electricity feed in and the growing power demand will require reliable generation and demand forecast. The use of forecast techniques to enable effective capacity utilisation of renewable energy sources such as wind and solar PV

* Corresponding author. Tel.: +91 9447889009.

E-mail addresses: mail2rajeevt@gmail.com (T. Rajeev), ashoks@nitc.ac.in (S. Ashok).

Nomenclature

$\beta_n(t)$	dynamic renewable factor	S_k	the net capital cost of the components in Rs
$G_n(t)$	total renewable energy produced in each time slot in kW h	S_{pv}	capital cost of the solar PV system in Rs
$D_n(t)$	total energy consumed in each time slot	S_{batt}	capital cost of the battery in Rs
E_n	unit energy price in Rs	$E_{batt}(t)$	battery energy storage potential in kW h
E_n^{export}	electricity export charge in Rs/kW h	$E_{Gmax}(t)$	peak PV generation in kW h.
E_n^{import}	electricity import charge in Rs/kW h	E_{pv}	energy generated by the PV array in kW h
E_T	the aggregated energy charges for a day in Rs	E_{avg}	average hourly demand during the sunny day time in kW h
S_y	net annual savings with solar PV system and battery in Rs	$E_{export}(t)$	energy export potential at any time frame in kW h
S_i	money earnings in Rs	$E_{Loadshift}$	shifting potential in kW h.
S_k	annualised capital cost of the components in Rs	$P_{Grid}(t)$	power exchange with the grid
S_g	money earnings owing to export of electricity into the grid in Rs	E_{BESS}	battery energy storage rating in kW h
		SOC_{min}	state of charge
		η	PV system efficiency

generators has been previously addressed in the literature [5]. Despite efforts to improve forecast techniques, they still incur in high error rates. The accuracy of forecasting is affected by the intermittency of renewable sources; to overcome this intermittency issue, complex forecasting engines and a mechanism for large-scale time series data management are required [6]. Here, the handling and processing of large-scale data are really an operational challenge.

The implementation of demand side management programs such as load shifting has become an active topic with the increased integration of rooftop solar PV and wind generators in the domestic sector, and several shifting algorithms have been proposed [7,8]. Such algorithms enable effective utilisation of resources with minimum storage measures in a grid structure with a large number of renewable energy sources [9]. The existing forecasting approaches used in the load-shifting scheme face the difficulty of prediction noise in a situation where both the sources and the loads are dynamic. A real-time approach that is independent of forecasting is more suitable to handle such a situation [10]. The implementation of a centralised load-shifting program on the consumer side is minimal due to the operational challenge of handling a huge amount of time series data for the execution of the program in domestic-level situations with the large-scale integration of renewable energy sources. Additionally, the complexity of a centralised system increases with the application of a dynamic load-shifting program [11].

Under such situations, a localised scheme is more effective than the existing centralised methods for demand side management [12]. The advantage of the localised scheme is the reduced amount of data exchange between the devices of the user and the utility. The shifting operations in the localised scheme can be achieved without the intervention of the utility by using smart metering, communication equipment and the associated hardware and software at the consumer side. Thus, the overall communication burden is reduced [13]. Indeed, a huge amount of data transfer is required because the measurement of the demand and generation is performed on a timely basis in any household.

In a grid connected system, utilities prefer to use incentive based load-shifting program to avoid power fluctuations in the grid and to improve stability [14]. Detailed investigations on this subject also reveal that incentive based DSM program is suitable to bring consumer involvement in such a program [15,16]. Incentive to the consumer via pricing aligned with the load-shifting operations encourages demand side management program in the domestic sector. Recently, utility companies have started introducing automated meter reading systems (AMR) in their distribution network to remotely collect data from meters and consumer premises [17,18]. The AMR system enables time of use pricing

and load-shifting via an integrated router gateway in each dwelling. The huge amount of heterogeneous information collected by the metering and monitoring infrastructures requires a computing platform designed for supporting data management services that are able to meet real time requirements of load-shifting applications. To handle these data, a suitable platform that is, capable of storing a significant amount of data, and has fast processing capability with good computational facilities is required [19]. These IT requirements can be met with minimum hardware using the virtualised storage environment of cloud computing [20,21]. In this context, a general cloud framework integrated with smart meter and wireless sensor technology is proposed as a viable solution to address the aforementioned issues. Demand side management program based on multi agent system was introduced to enable automatic operations [22,23].

In this paper, DSM program based on multi-agent system is presented. The multi-agent system used a single software framework for the implementation of a DSM program at the household with utility level access and monitoring facility. The key focus of this approach is to enable meter data management, higher level of monitoring, verification and execution of dynamic operations in a single framework. In the proposed load-shifting program, the status of the generation and demand are computed locally in each time frame, and the shifting is executed as required. The program is one providing incentives to the consumer to perform load-shifting activities that are aligned with the dynamic load-shifting operation. The dynamic renewable factor is introduced in the load-shifting program to eliminate the requirement of forecasting. A cloud computing framework with a simple client node at the consumer end is proposed for addressing the coordination, data storage and computing needs of the dynamic load-shifting program. An optimisation method taking into account the generation, demand and other operational constraints is also formulated to determine the feasible capacity of solar PV generators for a consumer and the minimum battery capacity required for the load-shifting program.

The rest of the paper is as follows. Section 2 explains the proposed dynamic load-shifting program. Simulated case studies to evaluate the effectiveness of dynamic load-shifting programs in the domestic sector and their impact on large electric power systems are described in Section 3. The results and discussions are presented in Section 4 and the paper is concluded in Section 5.

2. The proposed dynamic load-shifting program

Multi-agent based load-shifting operations in a cloud computing framework are used to simulate and evaluate the performance

Download English Version:

<https://daneshyari.com/en/article/6687556>

Download Persian Version:

<https://daneshyari.com/article/6687556>

[Daneshyari.com](https://daneshyari.com)