IoT based energy efficient architecture for integrated Smart Grid

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Abstract. The emergence of Smart Grid (SG) plays a vital role in energy generation and distribution system. As SG is the association of numerous applications, this can be properly utilized to reduce the energy consumption. Hence, in this work, a new architecture is proposed to optimize the usage of RES effectively. This proposed architecture utilizes IoT for gathering the power consumption profile of the devices. Based on this profile, a schedule for a device is generated by the Micro Grid. The analysis shows the efficiency of proposed architecture.

Keywords: Smart grid, IOT, Micro grid, Integrated network

1. Introduction

The rapid rise in demand for fossil fuels have made us to graze towards an alternate energy sources like solar, wind etc., From the survey analysis, it could be found that, in developed countries, around 37% of produced energy is utilized by buildings[1], 28% by industrial sectors and 32% by transposition. Hence, all over the world, the governments of all countries are encouraging the researches to develop a new conception called “Smart Grid” [2]. The main objective of this SG is to manage the increasing energy demand. It includes a numerous communication technologies in it. These technologies could improve the efficiency, scalability and consistency of the conventional power grid. SG offers a bidirectional communication between consumers and electricity providers. SG can automatically diminish the energy wastage by scheduling power consumption and optimizes the electrical energy usage [11]. This can be achieved using IoT topology. Hence, in the work, an efficient energy management of SG is carried out using IoT topology. Thus, the main objective of this work includes,

1. Designing IOT networks for transmitting & receiving data from consumers/devices and vice versa.
2. Control/reduces the energy consumption of devices.
3. Integration of RES with user end.

Thus, a numerous approaches have been adopted in the energy management of SG. Ref. [3] have proposed a topology to optimize RES system.[4] discussed about consumers participation in energy minimization. Thus Linear Programming (LP) models were proposed to observe the best combination of power supply sources with consumers [5]. [6] Proposed a concept of integration of RES generation and distribution within a small area to fulfill the power demands of a particular area. The smart grid system with bio gas was introduced [7]. This system was adapted only to houses. [8]Introduced a Genetic Algorithm (GA) based optimization for minimizing power cost of generating plants. Similarly, an optimization model using a leaf community SG using GA was projected. [9, 10] proposed a new topology for maximizing the supply using isolated operation. To study the effectiveness of this system, it was demonstrated over budapsettech. Thus, all the surveys reported so far have been concentrated only on the energy minimization. Keeping in view, this proposed topology aimed to cost reduction along with energy minimization. Cloud computing topology is adopted here.
2. **Structural design of a system**

Fig. 1 shows the structural design of the suggested system. It includes SG, energy sources and IOT networks.

![Diagram of structural design of a system]

**2.1 SG**

SG is the centralized one which controls the operation of whole system. The data received from IoT network is processed in the SG using cloud system [12]. It includes various power sources such as wind, Solar etc.,

**2.2 IoT**

IoT is a network which could be able to interconnect an object with the Internet. It works on the basis of protocol which enables a communication between the smart devices. Thus the concept of IoT emphases mainly on following concepts,
Things Basis

Internet Basis

and Semantic Basis.

The things based concept include sensors (RFID tags/cameras/GPS). The Internet based concept activates a communication between smart devices using communications technology and links them with an Internet. The semantic based concept follows many applications using smart devices [15, 16].

2.3 Incorporation of an IoT with SG

Usually SG comprises four main systems viz., generation/transmission/distribution and utilization. It may be applicable to these systems for monitoring/controlling etc. This proposed topology makes use of cloud computing platform for modeling/data storage and also for, computation/analysis. This cloud platform provides high security/reliability and configurability communication between it and the user. As it is a user friendly web interface, it was adopted in this proposed topology [17-20].

3. Implementation of proposed topology

The energy consumption time at the consumers end is identified using sensors. Thus, the collected data is transmitted via high capacity node, with the help of clouds. This cloud in turn forms the real time processing and implements off loading condition to save the energy consumption. The main objective of this work is efficiency energy management at lower cost [13,14]. This can be obtained by two steps.

1: The devices can be scheduled according to their priorities.
2: The power consumed by these devices is minimized according to their priorities.

So, the devices used at the consumer end is subjected to achieve following objectives

\[ P_{\text{required}} < P_{\text{RES}} \]

Subject to

\[ P_{\text{wind}} \leq P_{\text{wind\_limit}} \]
\[ P_{\text{solar}} \leq P_{\text{solar\_limit}} \]

Thus, now the grid starts to schedule the operation of device. Hence the scheduling time is denoted as \( t_s \in T \) \( T=24\text{hrs/day} \)

Before scheduling the time for devices, the grid categories the devices as delay tolerable devices (DTA\( \rightarrow \) Timed/regular appliances) and delay intolerable devices. Thus, total power required for DTA can be depicted as,

\[ P1=\{Pda1,Pda2,\ldots\ldots,Pda3\} \]

3.1 Analysis

In order to find out its efficiency of this proposed system, 5 houses are assumed to connect with SG. Hence, analysis has been performed by considering the regular appliances of household devices. Table 1 describes the specification of regular devices.
Table 1. Specifications (Regular Appliances)[8]

| Appliances      | Power Consumption (kW) | Time limit (Lower) | Time limit (Upper) | Precedence |
|-----------------|------------------------|--------------------|--------------------|------------|
| Air Conditioner| 1.45                   | 5                  | 24                 | 3          |
| Refrigerator    | 0.817                  | 5                  | 24                 | 1          |
| Water heater    | 4.62                   | 5                  | 24                 | 2          |

Thus, the algorithm for scheduling the times for appliance as follows.
T: = Set of all types of Timed Appliances
for all ∈ \(\text{T} \) do
Search for Idle time slots
If Idle Slots is Available then
Schedule all the devices at present condition
else
schedule all the devices in slots on the basis of minimum load
end if
end for
Thus the results obtained by implementing the proposed topology are depicted in Figs. 2 and 3.

![Power distribution with and without microgrid](image)

Fig.2 Power distribution with and without microgrid

From the figure, it is concluded that by implementing the proposed algorithm, the average power requirement for an hour decreases with the use of RES.
Fig. 3 displays the need of an extra energy required per day when the demand exceeds the limit of RES. Consider the situation, when there is no wind flow and PV is also reduced due to cloudy nature. Under this situation, if the RES limit is > 30 kW, then this proposed algorithm will considerably decrease the power purchase from outside and hence results in greenery environment.

4. CONCLUSION

In this work, the deployment of IoT in smart grid is analyzed. Thus, to optimize the operation of smart grid, it introduced a novel architecture using IoT. In this architecture, the energy consumed by the consumers were minimized by allocating energy based on the priority. The priority is given to the devices based on their demand. As a result, the flexibility over the generation unit will be increased and results in profitability. It also offer more secured operation under congestion emergencies. Apart from there, the result depicts that this algorithm will result in significant reduction of electricity cost. This architecture will also monitor the preventive measures and fault occurring in Transmission lines. As a on a whole, it is concluded that, this proposed architecture will provide better and secured operation over smart grid.

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