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Cooperative Application of IoT Modules to Increase the Efficiency of Power Plant and Solution to Duck Curve

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Abstract: *This paper describes the concept and the development of an IoT based system that can contribute significantly to the increase in efficiency of a turbine and thus increase the operational efficiency of a power plant. This system is aimed at reducing the overall daily fluctuations of the electrical energy demand by employing the use of IoT modules in households. Also, the proposed system can be a potential solution to the problem pertaining to the problem of 'Duck Curve' which has been discussed briefly in this paper as well. The concept is to shift the electricity usage of 'time-independent' demands such as pumping of water, charging of electronic gadgets like laptops, mobile phones, washing machines for clothes, etc. to the times where baseload or lower loads are observed in the grid. A mobile application is also developed for interaction regarding the time of use of the various types of equipment with the user and make the whole system more user-friendly.*

Key Words: *IoT Application, Duck Curve, Power Plant, Efficiency, Load Fluctuation, Grid Managing*

1. Introduction

It is a well-known fact that the demand for electric power is not constant round the clock. The fluctuations in the demand of the power are quite high and have peaks and valleys termed as peak load and baseload respectively. In order to cater to this need, special centers, known as State Load Dispatch Centre (SLDC), have to be set up. The prime function of the State Load Dispatch Centre is to instruct various power plants to keep operating or to operate at partial capacity in order to cater to the varying needs of the demand.

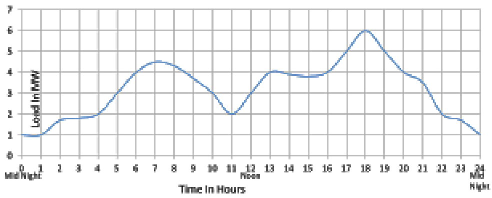

Fig.1: Load Curve [1]

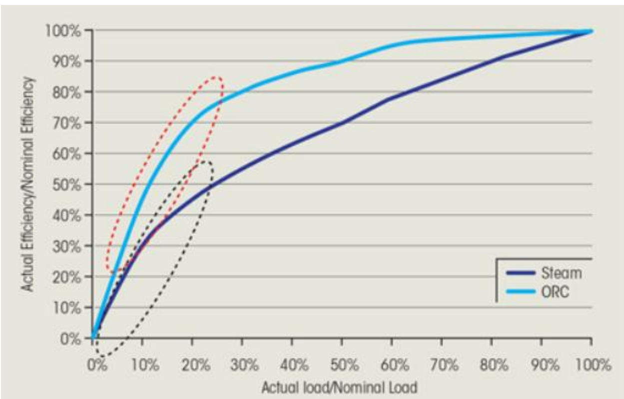

Fig.2: Efficiency vs. Load of a Turbine [2]

Now, due to this variation in the demand, many power plants have to be operated in part-load conditions. In part-load conditions, the turbine has to be run at capacities that are lower than its installed capacity. The part-load efficiency of any power plant can be exponentially lower than its efficiency at rated load. Thus, the operating power plant is supposed to use more fuel (or water in case of hydropower plants) to produce the same amount of electrical energy with highly reduced efficiency.

2. Duck Curve

Duck Curve is the term given to the curve of the net load on a power grid when the contribution of solar power in the overall generation is significant. Figure 3 shows a typical generation plot of a solar plant over the day. It can be intuitively seen that solar generation is concentrated in the daytime only. The difference between the total load demand and that being generated by renewable sources like solar energy is termed as 'Net load' on the grid. Figure 4 shows the curve of net load with significant solar generation.

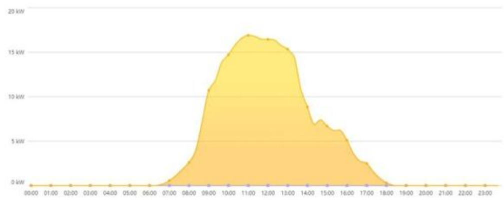

Fig.3: Solar Generation throughout the day [3]

This net load curve is also known as the Duck curve as it is shaped like a duck. Now, a problem arises as the day approaches the evening time. In the evening time, the demand for electricity attains its peak value. At the same time, the generation output from solar plants reduces to zero. Thus, the value of the net load increases very quickly and attains its maximum value of the day.

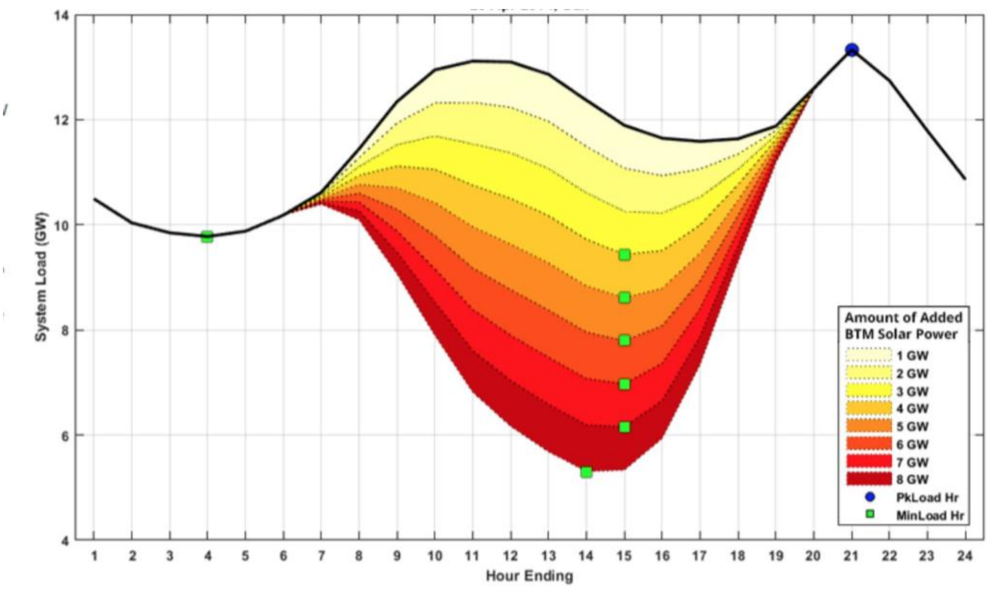

Fig.4: The Duck Curve [4]

Now, this situation creates problems for the power plants operating on fossil fuels as well as nuclear power plants. As these posses high starting and stopping 'inertia', these types of power plants prove to be highly uneconomic in conditions of frequent starting and stopping of generation. Hence, it creates a problem in managing the grid at times of peak demand and no solar generation. A potential solution to this problem can be to uniformly store the electrical energy produced by solar power while also running the thermal power plants. But this also comes with its costs and drawbacks.

3. Objective

The objective of the proposed system is to reduce the fluctuations in the demand for electrical energy. This can be done by shifting 'time independent' usage of the electricity to the times of lower or base demand for electricity. Time independent usage implies that portion of the overall consumption which does not depend on the time of their occurrence. For example, the charging of an electric vehicle does not depend on the time it has been charged at. Thus, the electric vehicle can be put to charging at the times of lower or base demand and made available for use. Thus, planning the usage in a bit of advance can be advantageous. This will serve a twofold purpose. One, it will lessen the peak load as the time-independent components at the peak load shall be shifted aptly to the times of lower demand. Second, the lean period of the electricity use would be using electrical energy that has been made available at cheaper rates.

Also, this system of usage of electricity by time-independent demands at lower demand times can potentially solve the problem associated with the Duck curve as it may reduce the need for energy storage to a considerable extend. This can be done by satisfying the time-independent demands at the time of solar generation in such a way that the thermal power plants can also operate throughout the day and hence eliminating the 'inertia' of frequent starting and stopping of these thermal power plants.

4. Proposed System Description

The proposed system achieves the objective by implementing the use of integrated IoT modules as a switch to operate the devices associated with the time-independent consumption of electricity as pointed out above. The schematic layout in the form of a block diagram is shown in the following figure which includes an integrated IoT enabled switching module with a 9V power supply and a mobile application.

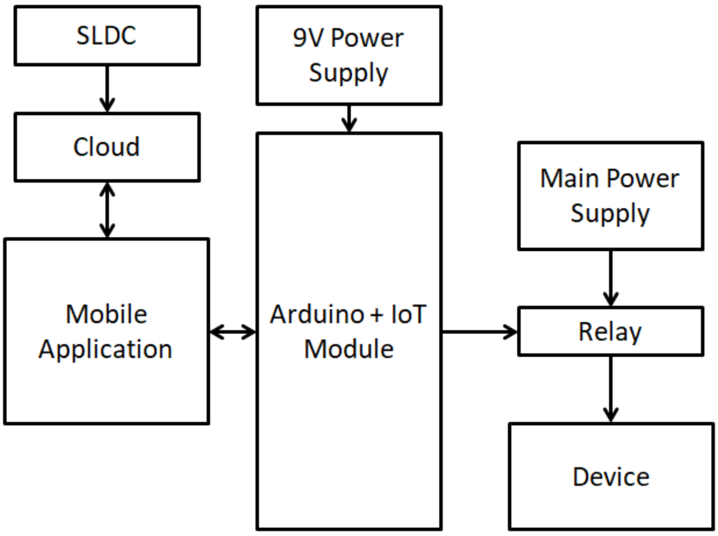

Fig.5: Block Diagram of the System

The system consists of a data cloud that fetches the real-time load demand figures from the SLDC (State Load Dispatch Centre). The cloud also stores data from the past. The cloud then passes on the relevant data to the mobile application. The mobile application upon reception of the data from the cloud decides and schedules the usage of various 'time independent' tasks in the time of lean demand. The mobile application also has a manual overwrite option which can be used to manually set the time of activity of any particular device. Here, the device refers to any electrical appliance which is considered to be having a 'time independent' function.

A single mobile application may be connected to many devices. Thus, each mobile application stores the unique ID of each of the IoT module that is connected to it. Each IoT module is supplied as a power source of 9V DC. Now, when a specific IoT module is instructed to operate a device, it switches on a relay which is then placed between the respective device and the main power supply of the device. Upon the operation of the relay, the power reaches to the device and it starts its operation. In reality, the 9V DC power source, integrated IoT module, and the relay setup will be contained in a compact housing with required ports for input and output of power supply.

5. Justification

In order to justify the proposed system, figure 6 can be taken into consideration as it portraits various activities that consume some amount of electrical energy. While time-dependent activities like watching television and other activities cannot be shifted and contribute to the peak loading, some time-independent activities like washing clothes and cleaning are performed throughout the day with small bumps in between. Thus, it can be justified that the employment of the proposed system may lead to the concentration of these activities that can be done at times of lower demand.

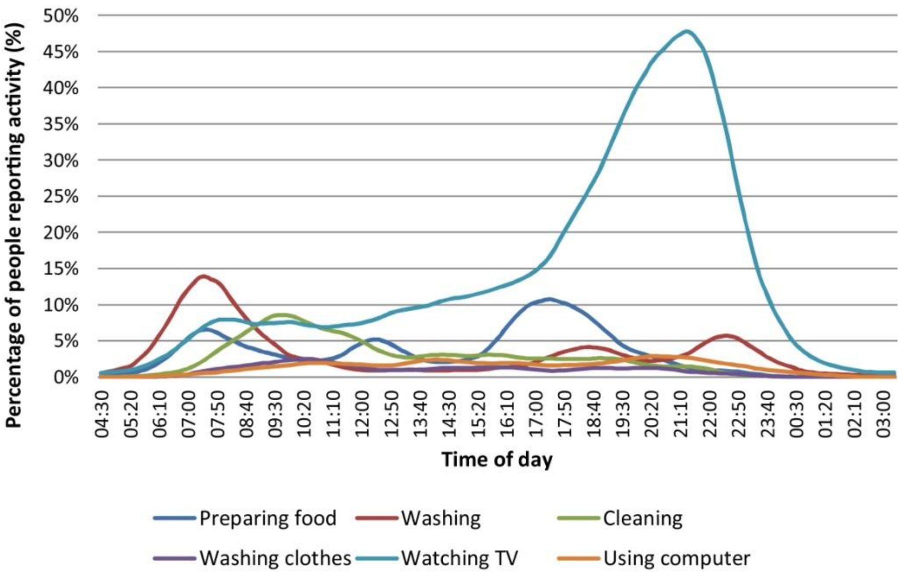

Fig.6: Concentration of different Activities [5]

6. Conclusion

It can be concluded that the proposed system can be effectively used in order to achieve the designated objective of lowering the fluctuation in the demand for electricity. The effectiveness of the proposed system can only be seen by the increase in the scale of the use of it. Also, it can be recommended that individual households can be initially lured by implementing the dynamic costing of the per-unit rate. As the number of households using the proposed system increases to a certain range, considerable changes in the load pattern can be observed in form of reduced fluctuations of the demand and hence, the lower per-unit rate can be applied statically.

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Biography

Suketu Parekh is currently a Mechanical Engineering student in Semester 6. His areas of interest involve Mobile Robotics, Machine Learning Algorithms and IoT systems among others. At present, he is working on the design and development of novel mechanisms for Mobile Robots.