APPLICATION OF ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING TO EVALUATE THE FEASIBILITY OF ENERGY INFRASTRUCTURE THROUGH SMART PLUG

Abstract

Evaluating the performance of an electrical appliances in a household is a very crucial step towards achieving energy efficiency. Currently, there are various solutions to assess the energy efficiency in the market yet they are lacking in re usability and feasibility in using the latest technological development.This proposed paper approaches the familiar concept of energy efficiency through the implementation of advanced artificial intelligence and machine learning models through a smart plug.This smart plug is found to increase energy efficiency and reports in efficient device using various algorithms and techniques. The technologies used are machine learning for data processing, artificial intelligence is used for text mining and self improving computer models. Statistics and analytics are used for data analysis and date presentation.

Keywords: Smart plug • Artificial Intelligence • Machine Learning • Energy Efficiency • Text Mining • Data Analytics

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I. INTRODUCTION

Industrial revolution in 18th century transformed the way energy is consumed across the world. The invent of steam engine lead to mechanization of production which increased the energy consumption at a scale never seen before. In 1800's, global energy consumption was at 5653 Terra Watt while energy consumption in 2019 was 1,73,340 Terra Watt. In India, annual primary energy consumption has increased to 10.06 percent in 2021 from 3.06 percent in 1966. That is a whopping 229 percent relative change in energy consumption. India with more than 140 crore population is consuming energy at a mind-boggling rate of 7000 Kilo Watt Hour per person in 2021 from 1200 Kilo Watt Hour in 1965. While electricity generation has reached only 1714 Terra Watt in 2021 which is inadequate in fulfilling our energy requirement and that is why there is frequent power cuts in the cities while only few hours of scheduled power is supplied in the villages.

Imagine Without electricity for few days to few months, mobile phones and communications would be dead, electric vehicles and appliances are useless, air conditioner and heaters are out, hospital backup power runs out and life comes to a standstill.Now reality is around 940 million(13% of world population) have no access to electricity. In India, 29.85 million people have no access to electricity in 2019. Even if the rest of the people have access to the electricity but disparity in access due to power cuts are hindering the nation's growth towards the target of developed nation.

From the above data, we can come to a conclusion that electricity is a critical factor in economic growth, technological growth, poverty alleviation and matter of fact sustainability of life on earth depends on the energy.Energy generation of a country or the world has many limiting factor such as natural resources, human resources, technological advancements and so on. Some factors can be controlled by the humans but many factors related to nature cannot be controlled by humans. What can be controlled by humans is achieving energy efficiency. Energy efficiency can be achieved by educating consumers at the user end while using advanced technology in production end will also help in achieving energy efficiency at both the ends.

Even United Nation's "Sustainable Development Goals 2030" has a goal at number 7 which addresses the "Affordable and Clean Energy" and emphasizes on the access to electricity, energy efficiency and use of renewable energy.Advancement in technology such as Light Emitting Diode(LED) and Liquid Crystal Display(LCD) instead of Cathode Ray Tube(CRT) technology, electric vehicles instead of fossil fuels, Brush less Direct Current Motor (BLDC) in place of traditional motors are good implementation at the manufacturing side. At the consumer side, variety of options are provided yet, people are unaware of these advancements or are price sensitive since latest technology comes at an extra cost. This knowledge gap and price sensitivity gap can be filled using Artificial Intelligence and machine learning which uses data to achieve energy efficiency.

II. BACKGROUND

Every households have come across a situation where they want to achieve energy efficiency in their house and reduce electricity bills but don't know where to start. They also take precautions in switching off lights, fans etc. if not used and yet their electricity bills are

high. The solution to the problem above is electronic appliances or home appliances and their aging issue or a faulty line. As home appliances age, they tend to consume more power which cannot be detected easily using traditional methods and that is where we use the latest technology such as Artificial intelligence, machine learning and internet of things to overcome the problem.

1. **Importance of the problem:** In our vast country of more than 140 crore population, purchase of consumer electronics and home appliances is at a CAGR annual growth rate of 1% as per Technavio Research report. This growth rate shows how latest electronics are purchased by the middle class and above. The latest technology has good energy efficiency such as 5 star rating energy consumption.

   Our concern is the middle and lower middle class who either purchase cheaper products due to lack of purchasing power or buy second hand used products which already have a degraded energy efficiency. Due to their current condition, further burden in form of higher electricity bills is a great concern since home appliances such as television, refrigerators have become a basic essentials to lead a life. Our target consumer is not just lower middle class but all class of people since electronic appliances have a shorter shelf life and degraded energy inefficient appliances are also a concern to all the segments of the society. Of course, reducing in power consumption further reduces financial burden on the society. This will also create a more sustainable environment for upcoming generations.

2. **Current solutions in the market:** There are many Artificial Intelligence based smart devices to improve the energy efficiency of a household in the market. Smart meters are available to manage energy consumption, smart homes are connected to mobile applications to control devices. Recently Alexa and Google Home are also available to make home smarter. Smart plugs are also available which can detect connected appliances through analysis of power consumption. These currently available smart devices need a lot of investment and may be rewiring of entire house or expert technician is required for the installation process. The gap in the market with respect to the use of technology is a low-cost smart plug which can monitor appliances and give a user friendly report stating any connected devices are faulty, consuming high power or any replacement is required along with detailed analysis of the data which tells how much power is consumed and reduction in electricity bill if faulty *appliance is repaired or replaced.*

III. SOLUTION AND METHODOLOGY

Our system is a synthesis of Internet of Things (IOT), Artificial intelligence (AI), Machine learning (ML), along with statistics and analytics. Amalgamation of the above technologies will create a recommendation system using various algorithms to give a desired output. IOT is implemented through a smart plug (which is like a normal three pin adaptor) that connects to a Wi-Fi and has a built-in support for Alexa and Google home. Artificial intelligence and machine learning runs the model. Statistics And analytics are used to process the model data and show report to the consumers in a crisp, detailed and clear manner. Data being the crucial component of this project, it would be mined using data mining techniques,

web scraping using Natural Language Processing, cleaned and analyzed using various complex algorithms and models to give the desired output.

1. **Workflow*:*** The main prerequisite for the system to run is connecting our smart plug to any home appliance, Wi-Fi network and pairing the same with the mobile application.

   Now the order of the work would be:

   - User needs to select the home appliance from our pre-loaded database such as categories, company, and model number.
   - If the user is not able to find the device then he can search from the app using voice command or enter details manually.
   - Once the user sets device information then he can use the device normally and our system starts monitoring and collects required data over a period of time.
   - Time frame to collect data varies from device to device and also on the user usage pattern.
   - Once enough data is gathered and processed by the system, then a report is generated with an in-depth details of power consumed, average rate of power consumption from similar devices , faulty or service needed will be displayed in a clear manner for understanding by the user.
   - Recommended steps to be taken will be given to the user based on the problem analysis.

Table 1: Home Appliances

Device	Age (Years)	Manufacturer Wattage	Current Wattage	Status
Air Conditioner	2	2000 Watts	2050 Watts	Normal
Washing Machine	3	800 Watts	870 Watts	Caution
Microwave Oven	2	1000 Watts	1100 Watts	Caution
Refrigerator	4	130 Watts	250 Watts	Check / Faulty

From the above Table 1: Home Appliances, let's take an example:

Case 1: Air Conditioner is 2 years old and has a rating of 2000 Watts per hour.It is consuming around 2050 Watts per hour which means it falls in the normal range and hence Status shows “Normal”.

Case 2: Washing machine is 3 years old and consumes 870 Watts per hour compared to 800 Watts per hour. It is consuming higher energy compared to air conditioner but is not too extreme since it is a 3 year old device and hence it is labeled as “Caution” to keep a watch

Case 3: Refrigerator which is 4 years old which is consuming 250 Watts per hour compared to 130 Watts per hour manufacturer rating. It is consuming 120 Watts per hour extra energy which is a matter of concern and has been labeled as “check /faulty”.

From the above case study we can understand that refrigerator is consuming 120 Watts per hour more power than manufacturer required rating and hence it needs to be either rectified or replaced.

2. Cost benefit analysis

Table 2: Power Consumption Comparison

Power Consumption At 130 Watt Per Hour	Power Consumption At 250 Watt Per Hour
Manufacturer wattage = 130 Watts / Hour	Manufacturer wattage = 250 Watts / Hour
Estimated Usage = 10 Hours / Day	Estimated Usage = 10 Hours / Day
Total Power Usage = 130 * 10 = 1310 = 1.3 KWH	Total Power Usage = 250 * 10 = 2500 = 2.5 KWH
Total Cost = 1.3 KWH * 365 days * Rs.7 = Rs 3321	Total Cost = 2.5 KWH * 365 days * Rs.7 = Rs. 6387
Annual Cost = Rs.3321	Annual Cost = Rs.6387
Monthly Cost = Rs. 276	Monthly Cost = Rs. 532

Using the above Table 2: Power consumption comparison, lets calculate the cost benefit analysis using refrigerator as an example.

The first column is power consumption at 130 Watts per hour and second column is faulty power consumption at 250 Watts per hour by the refrigerator. For convenience purpose, unit rate of power is taken at Rs.7 and estimated usage is taken as 10 hours per day.

- **Power consumption at 130 Watts per hour:** Manufacturer rating is 130 Watts per hour and estimated usage is 10 hours, therefore 1.3 Kilo watts per day is used. When total cost is calculated for 365 days at Rs.7 unit rate , total expenses comes to Rs.3321 (per year) and monthly charges is Rs. 276

- **Power consumption at 250 Watts per hour:** Manufacturer rating is 130 Watts per hour and estimated usage is 10 hours, but current consumption rate is 250 Watts per hour and therefore 2.5 Kilo watts per day is used. When total cost is calculated for 365 days at Rs.7 unit rate ,total expenses comes to Rs.6387 (per year) and monthly charges is Rs. 532.Therefore we can conclude that the faulty refrigerator is consuming more electricity and user has to pay Rs. 532- Rs. 276 = Rs.256 per month (Extra).

Hence when an user rectifies this issue of a faulty refrigerator then he can save Rs. 256 per month which calculates to Rs. 3072 annually.

IV. RESEARCH MODEL

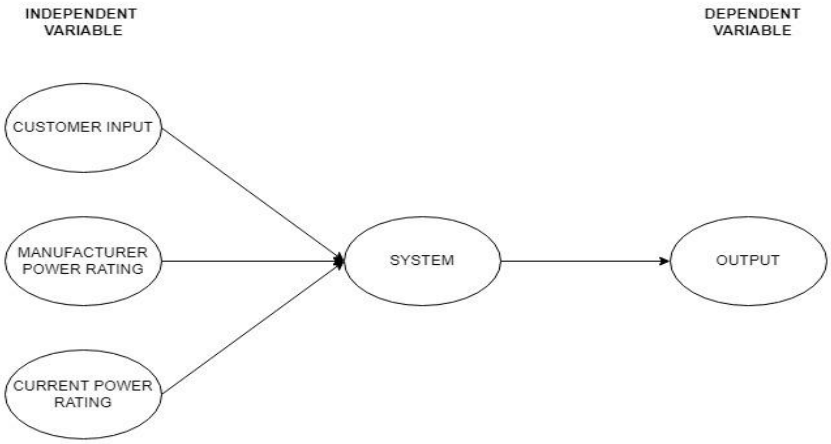

Figure 1: Relation between Variables

Above Figure 1: Relation between variables explains research model of our project where independent variables such as customer input, manufacturer rating and current rating data from the smart plug is fed into the system which uses various models and algorithms on the input data and generate output which will be a dependent variable. Here customer input will be selection of device model from various options available. Manufacturing rating is data mined or scrapped from web, while current rating is the values from the smart plug. Various algorithms such as Decision tree, KNN clustering and natural language processing are used to process and display meaningful data to the consumer.

1. Flowchart

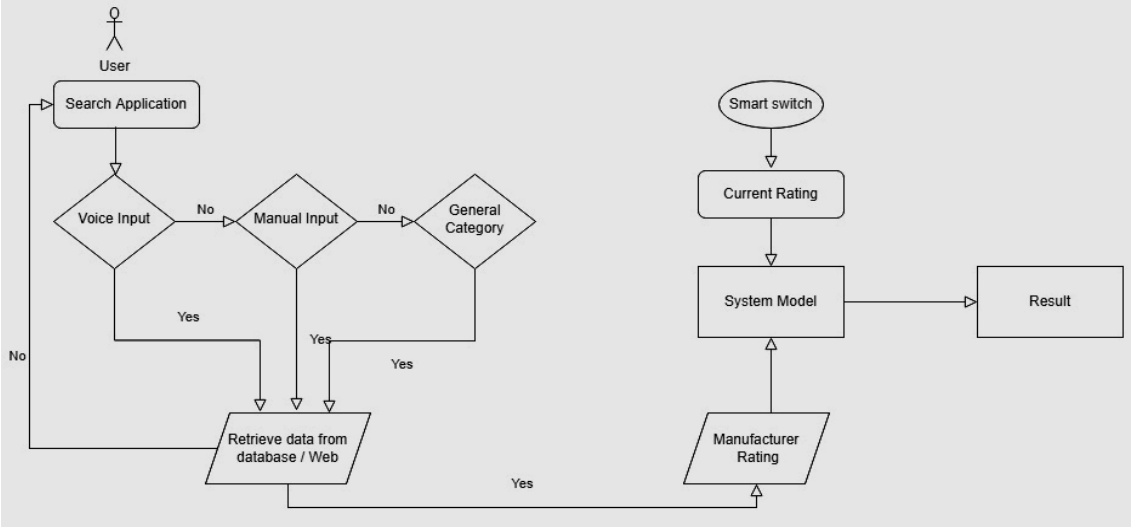

Figure 2: Flow Process of the System

Above Figure 2: Flow process of the system shows the complete flow process from start to finish of the system.

- First step starts from user input to the system which contains his model number of electrical appliance for data retrieval. Methods such as voice search, manual entry, general category selection is available. If any one method fails flow would get back to the user.
- After successful input from the user, data is retrieved from the database or by web scraping.
- This data is sent to the system model which also receives data from the smart plug.
- The system analyses data using various artificial intelligence and machine learning algorithms which are modeled to work on the data and desired output is generated for the user to understand the problem.

V. OUTPUT RESULTS

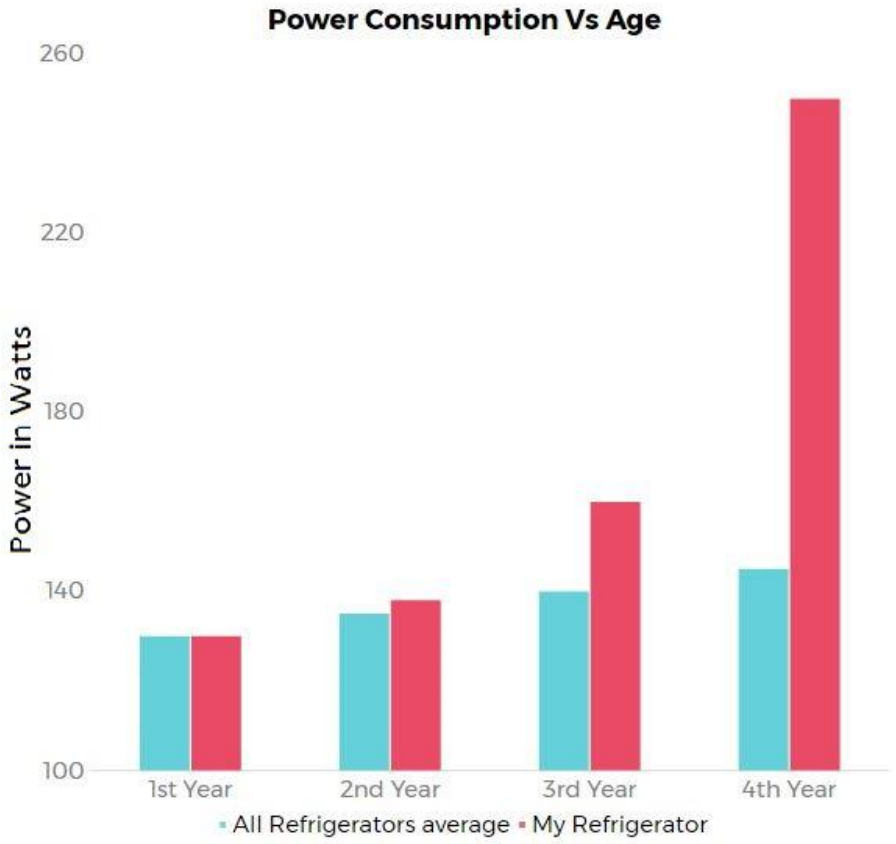

Figure 3: Bar chart of Power Consumption vs. Age

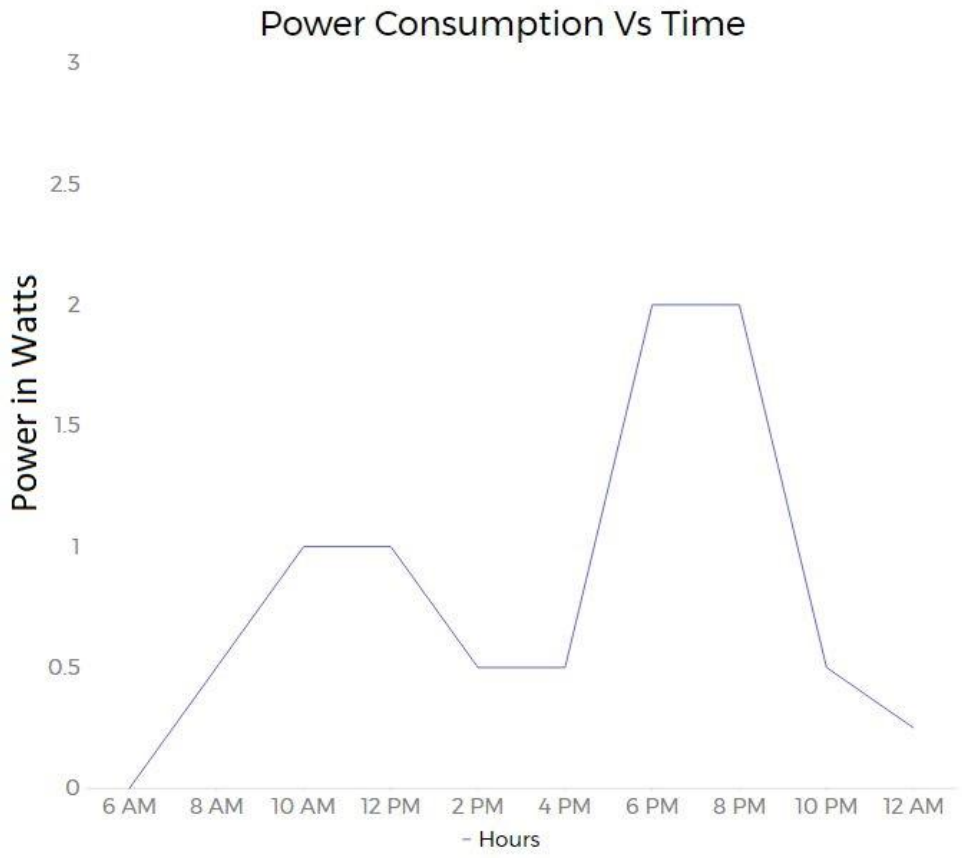

Figure 4: Line chart of Power consumption vs. Time

From the above sample result diagrams, Figure 3 and Figure 4, we can see that data being represented in different forms. Bar charts area showing "Age vs power consumption", line charts are showing " Power consumption over a day time " which is the data collected from the smart switch. Many such diagrams are generated for the user in order to understand the result deeply for making a meaningful decision. Generated report will also have suggestion to the user based on the data as shown for refrigerator example.

Steps to rectify the problem:

- Check for faulty socket
- Check for faulty lines
- Check for refrigerator coolant
- Check compressor performance
- Check freezer temperature
- Check permitted load
- Repair or replace for newer model

VI. CONCLUSION

Artificial intelligence is proving to be taking the globe towards a self reliant and green energy through its electric cars and bikes, home automation and even electric grid automation. This proposed paper is a small step in making our homes an energy efficiency place contributing to a greener environment. With the advancement in technology, we are at a phase where data can be used to solve plethora of problems and increase efficiency across many fields of science and technology. Once computers were unreachable to the general users but today computers are part and parcel of our lives from kitchen appliances to smartphones. Artificial Intelligence was also at a stage where it looked farfetched a decade ago but today it has entered our homes in form of automation, voice assistant and smart devices. This is just the beginning of a new era of advanced technological developments leading the world towards more sustainable environment.

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