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A hybrid technique of machine learning and data analytics for optimized distribution of renewable energy resources targeting smart energy management

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Abstract

The distributed generation in smart grids has become highly prevalent due to its inherent characteristics like robust, reachable, lossless and emission less. The increased usage of sensor devices, wireless and network communication, cloud computing and IoT (Internet of things) explores the merge of smartness in energy field which results in an extensive collection of data getting populated in the electricity sector. This paper proposes a hybrid machine learning with big data analytic techniques for optimized distribution of available energy resources targeting smart energy management. The system aims in handling smart energy management using the data received from conventional sources and various distributed generation sources like photovoltaic, wind, small hydro and biomass. For unsupervised power data an efficient clustering methodology such as grid based clustering has been incorporated for optimal distribution of energy received from the nodal and zone regions. For structured power data, support vector machine algorithm of supervised learning is used for smart distribution which performs classification and regression of the vast electricity data. Regressive analysis over electricity data across the country with respect to various regions is carried out to understand the energy consumption which gives the insight of energy deficit. Thus the machine learning hybrid techniques were performed over the collected data to validate the smart distribution and the result obtained ensures a substantial gain which leads to conservation of generated energy through smart energy management.

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1. Introduction

The increased usage of sensor devices, wireless and network communication, cloud computing and IoT (Internet of things) explores the merge of smartness in energy field [1]. The quantity of data gets accumulated rapidly with complicated data structure. Due to the impact of digitalization and penetration of latest technologies, the automation in the power energy field with respect to energy production and consumption is getting elevated[2][3]. The usage of energy produced by photovoltaic is increased in drastic manner compared to conventional power sources [4][5].Landscape of traditional power energy sectors getting much energized due to the insight of intelligence in machine learning and big data analytics techniques. Many researches are undergoing to address the various challenges faced in the power energy field handling energy and operational efficiency, managing renewable energy, stability and consistency, end user rendezvous and service enhancement [6].

1.1 Electricity consumption pattern

In India, the electricity consumption pattern has made remarkable transformation over the decades. Due to energy conservation practices and energy efficiency techniques the power consumption in industries got declined leading to overall benefit of 17% [7]. In contradict, due to modern and smart equipment's usage in domestic section and smart farming in agriculture domain there is an increased consumption ranging from 10 to 12% rise [8]. **Fig.**1 shows the graphical representation of power consumption analysis during the period 2013 to 2018.

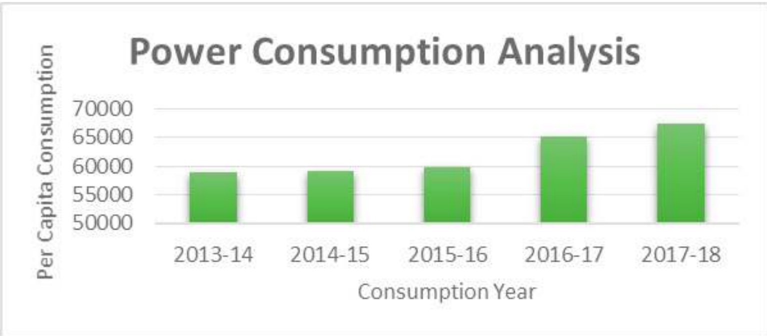

Fig. 1. Power Consumption Analysis

1.2 Advance Metering Infrastructure in big data

Smart energy system is the conjunction of the intelligent devices with Internet to automate the energy management process. AMI (Advanced Metering Infrastructure) is a convergence of two-way communication network to guarantee error-free remote meter reading ensuring smart grid [9]. The AMI consist of smart meters, Communication network, meter data acquisition system and Meter Data Management System (MDMS). Periodically the smart meter of AMI collects electricity consumption details of each consumer making a massive collection of data [10]. This MDMS module of AMI plays a vital role in processing enormous meter reading leading to populating big data for its further analyzes. A substantial implementation of AMI is that every node of consumer may help us to perform the analyses in more accurate over billions of electricity data. AMI in India's grid systems assures system reliability which reduces power outages, decreasing electricity cost, eradicating electricity theft [11].

2. Proposed Smart Energy Management process model

To attain the smart energy distribution using machine learning and big data analytics a process model of is proposed for the energy received from traditional generation versus distributed generation. Fig. 2 shows the block view of smart energy management process model.

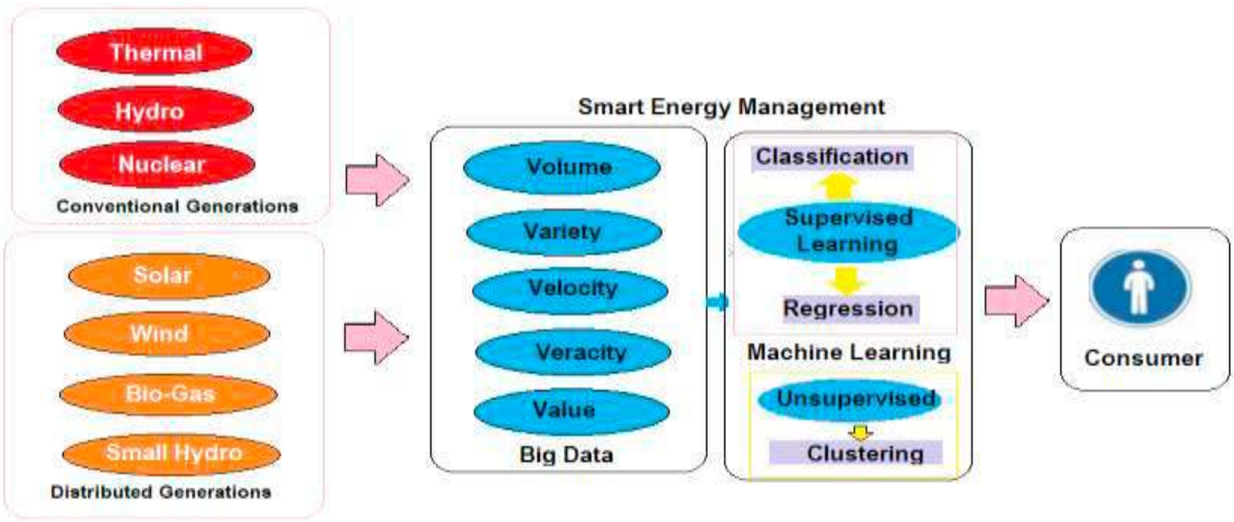

Fig. 2. Smart Energy Management Process Model

2.1 Machine learning for Electricity data

The division of artificial intelligence to analyze more complex data to train machines for decision making and problem solving to discover hidden characteristics of large dataset. Due to the existence of 5 V's (Volume, Variety, Velocity, Veracity, Value) in electricity sector, big data analysis is suggested to carry out for large volume of electricity data generated at various velocity from different sources like solar, wind, bio-gas, and traditional approaches in a useful and trustworthy way [12]. The analyzed data is then distributed smartly using machine learning techniques in an efficient manner. This paper targets in analysing the data by both unsupervised learning and supervised learning methods. For unlabelled dataset,grid based clustering of unsupervised learning methodology is implemented to cluster the energy data for optimal distribution. For a structured dataset, support vector machine of supervised learning methods were used for smart distribution. Fig. 3 represents the energy generation of various renewable sources like solar, wind, hydro and bio gas.

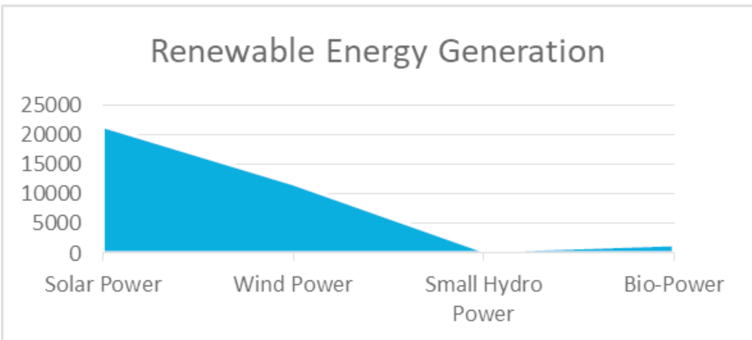

Fig. 3. Renewable Energy Generation

2.2 Grid based clustering for unsupervised power data

The system may undergo various clustering / classification of learning such as unsupervised learning, supervised and semi-supervised learning [13]. A raw data received from various energy sources without labels are considered as unsupervised data. So for unsupervised power data an efficient clustering methodology such as grid based clustering has been incorporated for optimal distribution of energy received from the nodal and zone regions. In this grid based clustering technique, the unsupervised electricity data are partitioned to custom into a grid structure with varying number of cells. Initially a grid structure with blocks of energy sources were created with “not active blocks” then clustering is performed until there is no more “not clustered blocks”. Grid based clustering ensures very fast processing as it always exploits the benefit of hierarchical and subspace clustering techniques. Fig. 4 shows the outcome of grid based clustering over unsupervised data.

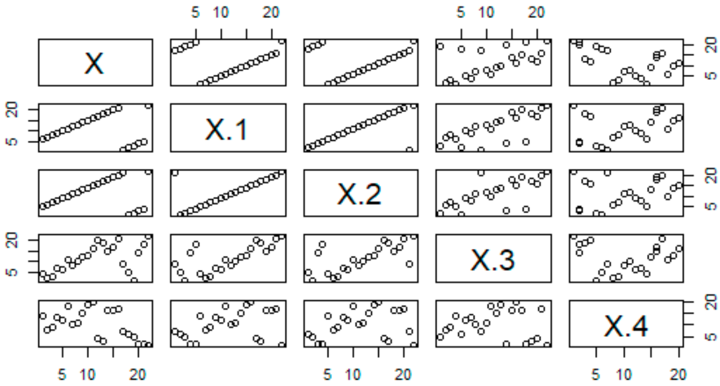

Fig. 4. Grid based clustering for electricity data

2.3 Support Vector Machines for supervised power data

The cutting edge technologies in energy sectors ensures the recent data customized under supervised data with proper labels [14]. As electric dataset has high probability density for classifying these power dataset, Support Vector machines (SVM) of supervised learning models is used to analyse the electricity data generated by conventional generation (CG) and distributed generation (DG). Since SVM ensures the optimal way of segregating the groups in high dimensional spaces with non-linear partitioning through kernel function. In this model, a decision boundary called a grid is created to make further predictions. Using contour function with level=0.5, a curve based Bayes Decision boundary is created. At first, a prediction is set on the grid based on the total amount of electricity generated using CG and DG. Then a distribution of generated power is made set to go based on the decision value “TRUE”. This will yield an attribute for making decision over distribution. Fig. 5 shows the non- linear SVM classification for conventional generation and distributed generation, representing T1 as total generation of energy and T2 as generation type (CG vs DG).

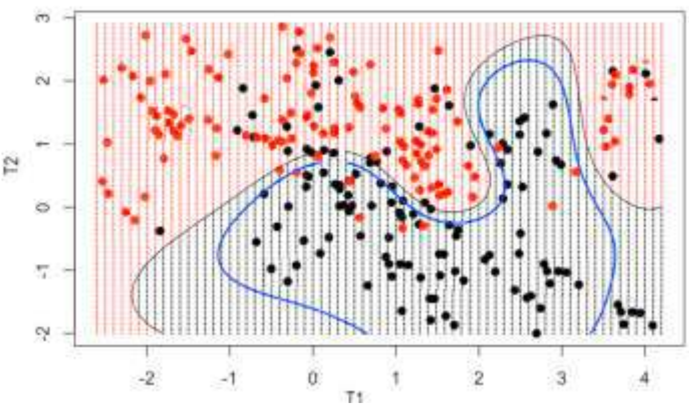

Fig. 5. SVM classification for CG vs DG

3. Results

Smart energy distribution is performed after accomplishing the appropriate clustering / classification techniques of machine learning for the various power generated from conventional as well as renewable resources. Regressive analysis over electricity data across the country with respect to various regions is carried out to understand the energy consumption. Fig. 6 shows the India's region wise energy demand analysis concentrating on Northern-Eastern, Eastern, Southern, Western, Northern regions. There exist a consistent deficit in the distribution in all the regions.

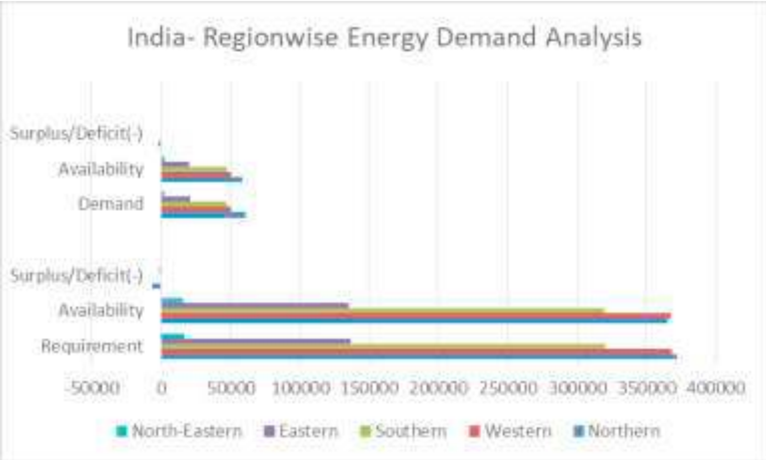

Fig. 6. Region wise Energy Demand Analysis

Fig. 7 represents the graphical view of smart energy gain achieved through SVM machine learning techniques. This proposed hybrid technique of machine learning and data analytics for optimized distribution of renewable energy resources targeting smart energy management ensures a gradual gain in energy conservation through smart distribution.

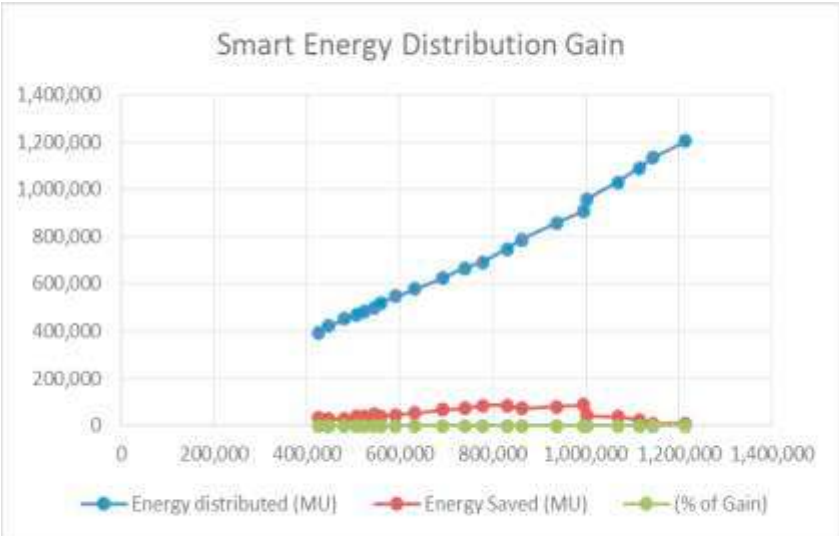

Fig. 7. Smart Energy Distribution Gain

4. Future scope of Smart Energy Management in Tamilnadu

4.1 Evolution in electricity for 24X7 supply

With joint initiative of state and central government of India, Tamil Nadu is a leading state in instigation nonstop 24X7 energy distribution to all the sectors ensuring 100% electrification even in all villages of the state. The electricity sector of the state had already endorsed peak surplus in year 2016 and has continued in forthcoming years. Complementing domestic consumers, the State Government of Tamilnadu affords 100 units of free electricity bi-monthly to all categories. The State has made substantial advancement in escalating access and availability of electricity at various levels. Survey says that compared to overall electrification of India, Tamil Nadu achieves higher household level electrification approximating 93.4% with respect to national global average of 67.2% which enables the state to ensure zero peak deficit. To meet all the demands of the consumers, various renewable units have been implemented to generate the electric energy [15]. In this work, a novel machine learning technique is proposed to distribute the electric data generated from various renewable sources.

4.2 State Transmission Strategy

Currently TANGEDCO guarantees the energy distribution with various utility in distribution network like Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) across the state. Under this scheme they increased the number of high tension (HT) distribution transformer from 2,64,029 to 320,681 and 6,09,544 kms to 644,603 kms of low tension (LT) during the year 2016 to 2019 [16]. Apart from hardware layout in the distribution system, this work proposes an intelligent hybrid machine learning technique to support the distribution network of various renewable resources in Tamilnadu. As this research work focuses on distribution of scalable electricity data, distributed machine learning techniques may be used for its efficient distribution. Distributed Machine learning (DML) is a multidisciplinary domain integrating theoretical computation, machine learning for optimization over large distributed and storage data.

4.3 Distributed machine learning in power sector

Owing to the distributed nature of electric data, the large data got stored in two different fragments such as horizontal and vertical fragmentation. In former case, the subsets of the data instances get stored at different location. In later case, the subsets of attributes of those instances get stored at different location.

5. Conclusion

In energy sector, cutting edge technologies such as smart meter helps to gather all the electricity data and provides very large amount of data from conventional as well as distributed generations. Thus, this work proposed a process model using big data analysis and machine learning techniques such as support vector machine to distribute the generated energy in an efficient manner ensuring smart energy management. These may be employed in different sectors such as industry, institutions and gated community to resolve various issues emerged through renewable source distribution. It also addresses the various challenges emerged out in the Infrastructure of Information Technology, Government and private sectors relevant to electricity data gathering, processing, clustering, analysis, integration, security, sharing and governance. However, there are few major challenges like stream lining of electricity data to meet very high demand during crucial / emergency period are yet to be addressed to accomplish fully automated smart energy management.

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