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Energy Optimization in Smart Grid using Tensor Decomposition

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Abstract- In India energy crisis has become one of the primary concern for its development and economic growth. The gap between power demand of users and its supply is incrementing day by day. Moreover, a large portion of the power plants depend on petroleum derivative and have the danger of being phased out in future. In this paper, we consider these issues by adjusting the power supply and demand, concentrating fundamentally on Disseminated Energy Resources (DER). During off peak hour's residual energy from DER will be stored in the proposed storage arrangement. The proactive consumers (pro-summer) in the demand side will have the scope to sell this stored energy to the national grid during peak hours in a proposed smart bidirectional network. Finally, grid monitoring and metering interface with an advanced control mechanism has been developed, which is expected to increase the extendibility of the pro-summer to handle their energy usage and costs. We have proposed a mechanism known as Tensor Decomposition (TD), in which we combined the smart meter rating produced from different sources into single dimension using MATLAB and finally applied Principle Component Analysis (PCA) to determine the error rate as compared to that of actual rate. Result obtained after applied the TD mechanism over Smart Grid (SG) data set are encouraging as compared to other preexisting approaches.

Keywords- Smart Grid; Principle Component Analysis; Tensor Decomposition; Energy

I. INTRODUCTION

The SGs are innovative and modern electric power grid management tool and infrastructure for increased reliability and efficiency through automated controlling system, high-power converters, metering and sensing technologies, modern communications infrastructure, and modernization in energy management techniques based on the availability of energy and network and optimization in demand. There are four ways to do optimization in SG [1-2]:

- Generation optimization
- Transmission optimization
- Demand management
- Distribution optimization

Focus of all four is to optimize the non-utilized energy during peak hours and non-peak hours so distribution optimization is best suited for this category. Mostly current grids were implemented and designed 120 years ago and unlike other commodities electricity has to be used, when it is generated we cannot store it [3-4]. Besides all this demand for power changes from time to time and the load in peak hours may be as many times as load in o-peak hours. This become a big challenge nowadays for power suppliers, as they have to full the power-demand in peak hours by utilizing during non-peak hours. One of the major goal of suppliers is to reduce the operating cost of load in peak-hours and defer the new investment to the power grid. Time, weather and type of consumers (i.e residential, commercial or industrial) are the factors that primarily affect the power demand.

Form the past 50 years traditional grids continuously struggling with modern challenges, such as stability in power supply, when there is an entry of secondary power generation source. High demand for electricity supply and weak control as well as management of distribution network. So, to keep all this challenges into existence a SG came up with new innovative ideas like optimizing asset utilization and operating efficiency. In this paper, we present an idea of optimizing the non-utilized energy during peak and non-peak hours and also estimate the demand supply response curve. To achieve this objective, we understand following terms such as demand-response and demand-side management, grid optimization, advanced metering, advanced utility control, energy storage, distributed generation sources.

In grid energy storage, we can store energy on a large scale as in traditional power grid, electricity must be consumed and produced simultaneously. So through grid energy, we can transfer load from peak hours to non-peak hours and it also improve quality of power [5]. Shifting load from peak hours to o-peak hours:

- Improving utilization of asset of existing methods.
- Reduction in investment requirement for new power plants.
- Reduction in investment to increase distribution and transmission limits. Transferring low costs to consumers.

There are some measures through which improvement in power quality achieved:

- Regulation in frequency: Energy storage in grid can quickly map the increasing demand.
- Voltage regulation: Energy storage in grid supplies reactive proles.

Figure 1 shows the data of last eight years energy consumption from the households in respect of on-peak hours, o-peak hours, mid peak hours, and total non-utilized energy from last years. So there is an urgent need to provide solution for optimize this non-utilized energy using TD. Figure 2 describes the analysis of demands of users with the Time of day and Figure 3 shows the analysis for averaged consumption with time of day for the household's demand of supply.

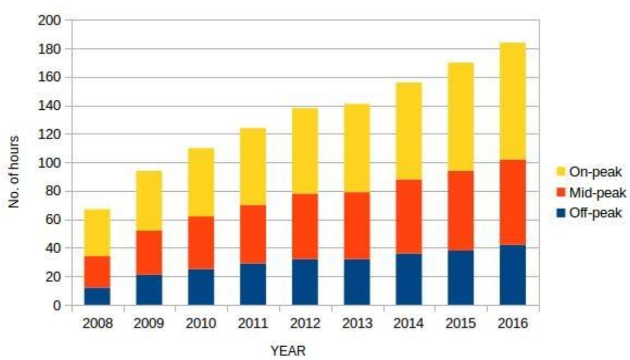

Fig. 1. Years-wise energy consumption from the households w.r.t. on-peak hours, off peak hours, mid peak hours, and total non-utilized energy

Research Contribution of This Paper

This paper have following research contributions:

- To optimize the non-utilized energy during peak and non-peak hours.
- To estimate the demand supply response curve from above objective.

In-order to achieve the above mentioned objective we have proposed a model using TD that collects the data set from various areas like industry and residential. Then we apply singular value decomposition and principle decomposition for the analysis of same.

- To identify and monitor the relevant readings of the smart meter indicating the power consumption by applying map reduce method using spark.

Organization

The remaining portion of paper is organized as follows: Related work is briefly discussed in Section II. Section III highlights Map reduce Efficiency with highly distributed data. Section IV gives results and last section V conclude our work with future scope.

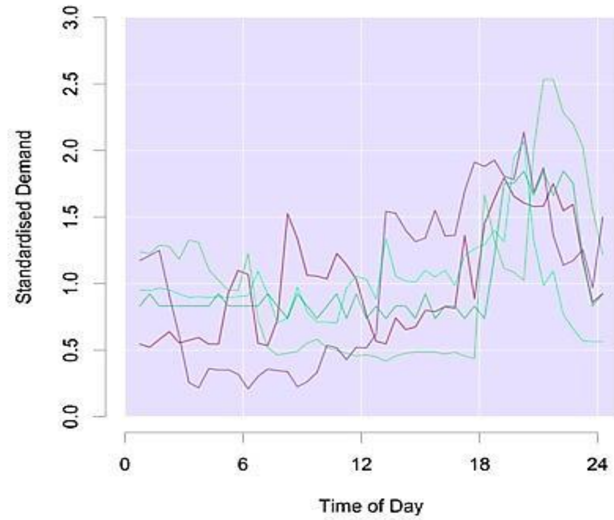

Fig. 2. Demand of users Vs time of day (year wise)

II. Related Work

Jozi A. *et al.* [6] proposed an execution benchmark for smart meter examination and exhibited an information generator for making very large smart meter informational datasets. They enhanced the productivity and viability of smart meters information mining calculations, counting parallel usage utilizing hive. They gave a general time arrangement examination benchmark for a more extensive scope of utilizations. Iftikar N.*et al.*[7] proposed a consumers demand response as far as value extendibility was measured. The observed consumers have made more grounded request reaction to the value signals amid winter than in summer and protected monetarily through better control of their power utilization design amid pinnacle hours. In any case, the cost versatility of pinnacle request, request reaction of clients in connection to the value level of the appropriation levy remained generally powerless. The general motivating forces from value signs are additionally constrained. Based on the estimations of this review, additionally think about on person family unit which performed remarkably in balancing out power utilization is accepted to bring better bits of knowledge into what mimic clients to partake and reaction.

Noda T. *et al.*[8] used direct programming to acquire a deterministic booking arrangement and utilized a vitality utilization adjustment variable to represent vulnerabilities. They utilized the day-ahead evaluating information of Ameren

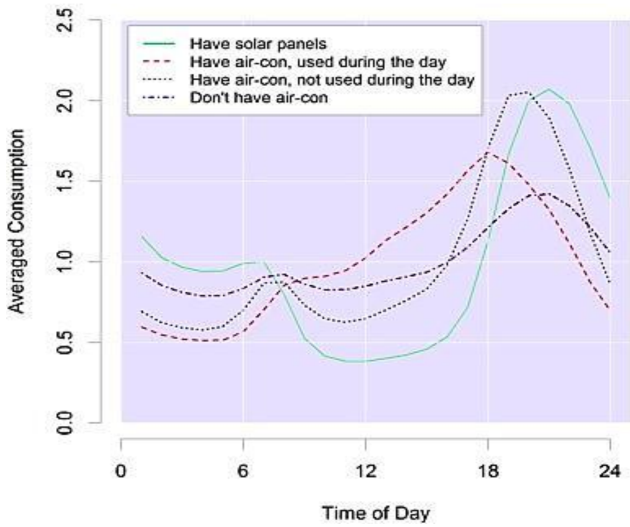

Fig. 3. Analysis for averaged consumption with time of day for the household's demand of supply

Illinois Control Corporation as the contribution to their model and two sets of sun powered photovoltaic module of Kyocera Solar Incorporation as the sun powered vitality hotspot for the model. Their model accomplishes in the vicinity of 0.41 and 0.24 diminishment of consumption over conventional deterministic plans and gives a timetable inside 10 seconds. Dong Q. *et al*.[9] distinguished different sorts of machines with changing burden sorts like shift able, warm, interruptible, and non-sensible. They utilized a Mixed Integer Linear Programming (MILP) and also done a heuristic calculation to tackle the NP-difficult issue. The target capacities are cost minimization and solace boost through booking inclinations and climatic control.

Arrigoni C. *et al*.[10] introduced a novel traversal and pruning calculation to plan thermostatically controlled family unit burdens to advance a target considering both consumption also, comfort. This calculation has optimality, heartiness, adaptability and speed. Later on Chen Q. *et al*.[11] consolidate the power stockpiling arrangements in the booking issue by arranging loads as vitality capacity framework, non-interruptible burdens, and thermodynamic loads. The target work incorporates electric, thermodynamic, financial, comfort, and natural parameters.

Kulkarni S.A. *et al*.[12] displayed a capacity reception cycle boosting the utilization of vitality stockpiling everywhere scales with variable rates what's more, pinnacle request extra charge. They demonstrated that purchasers can smooth their request by 0.18 of the base ideal limit to smooth framework request of a brought together framework. Agentis A. *et al*.[13] arranged apparatuses in light of sort of vitality utilization and relegate dynamic need in the booking process. Raei S. *et al*.[14] consolidated both the dynamic and responsive power request that utilized a non-straight load streamlining technique in a genuine time evaluating condition. The booking of utilization is studied for three client bunches modern, business, and private, and for three load periods crest stack, level load, also, o-pinnacle stack periods.

Dalmini F. *et al*.[15] proposed that by moving the heap from top hours to o-pinnacle hours in every family by means of a same value can move the total top to the already o-pinnacle zone. Additionally they considered a cost for postponement of begin of operation. Ultimate objective was to appropriate this accessible power to all families in this way limiting aggregate expenses. Goudarzi *et al*.[16] exhibit a heap versatile valuing theory gured as a shut circle Stackelberg amusement. The creators show that a group ideal can be accomplished by the proposed approach since the service organization can instigate a helpful conduct from the client. Yan B. *et al*.[17] adjust the singular optimality to social optimality by methods for an appropriated calculation. The service organization gathers these conjectures from all family units and produces a cost in light of its cost work. This cost is then distributed what's more, the individual family units reschedule their utilization.

Cardosa M. *et. al*.[18] proposed evaluating approaches in two diverse situations to help offices plan their power utilization. They work with a TOU (Time of-Use)- subordinate vitality estimating capacity and a TOU and aggregate power utilization subordinate vitality valuing capacity. They utilize heuristics to proficiently limit the buyer's power use and exhibit request forming capacity of the techniques.

III. MAP REDUCE EFFICIENCY WITH HIGHLY DISTRIBUTED DATA

In this paper we have used MapReduce with highly distributed data. MapReduce is used for high performance computing over a large and distributed data sets worldwide [18]. So, we have to collect the distributed source data on a separate data centers located across the globe. [18] shows the traditional single cluster MapReduce setup. They proposed three possible approach local, global, and distributed multiple MapReduce(DMR) clusters at several locations. In local MapReduce(LMR) approach the collection of distributed data into a centralized location from the Mapreduce cluster [18]. This would tend to a highly coupled environment for MapReduce. This may lead to high data transfer costs because it was not possible to transfer or move all source data at one location, when computing resources were also distributed.

In second approach i.e global Mapreduce (GMR) cluster deployed over wide resources to process data on a larger set of global resources. This would tend to loosely coupled system which lead to higher run time costs and even larger amount of intermediate data moved around the widely distributed systems. The third approach overcome the drawbacks of above two approaches. Multiple clusters were setup at several locations and combine their respective results in a second level MapReduce. But computational delay may occur because when the rest level MapReduce computation is completed then only and second level computation is possible. Some basic factors would take into consideration while designing an architecture for the MapReduce clusters. This paper shows the three architectures of MapReduce given the distributed data and resources and evaluate their performance over several workloads, as given in below mentioned code. We utilized two platforms:

- PlanetLab- Internet scale environments
- Amazon EC2- Datacenter scale infrastructure

```
from pyspark.sql import SparkSession
from pyspark.sql import Row
import pyspark.sql.functions as func

spark = SparkSession \
    .builder \
    .appName("Python Spark SQL basic example") \
    .config("spark.some.config.option", "some-value") \
    .getOrCreate()

sc = spark.sparkContext

lines = sc.textFile("smartgrid.tsv")

lines = lines.zipWithIndex().filter(lambda (row,index): index > 0).keys()


parts = lines.map(lambda l: l.split("\t"))
distribution = parts.map(lambda p: Row(PrimeRecipient=p[1], Resi_Customer=int(p
  [2]),Indus_Customer=int(p[3]),Comm_Customer=int(p[4]),Total_Customer=int(p[5])))
mDF = spark.createDataFrame(distribution)
qaDF = mDF.groupBy('PrimeRecipient').agg(func.sum(mDF.Resi_Customer).alias
  ("Residential"),func.sum(mDF.Indus_Customer).alias("Industrial"),func.sum
  (mDF.Comm_Customer).alias("Commercial"),func.sum(mDF.Total_Customer).alias
  ("Total_count"))
toporder = qaDF.sort(qaDF.Total_count.asc()).take(20);
kDF=spark.createDataFrame(toporder)
print("**************************************************************")

print kDF.show()

print("**************************************************************")
```

IV. Result and Discussion

To validation our objectives, in this paper, we have selected widely distributed data and computational resources across the network and also the MapReduce jobs executed over all on the combined data. Earlier Hadoop and its le system HDFS (Hadoop Distributed File System) were used to reduce the workload of the system. Data from the several resources were rest moved into

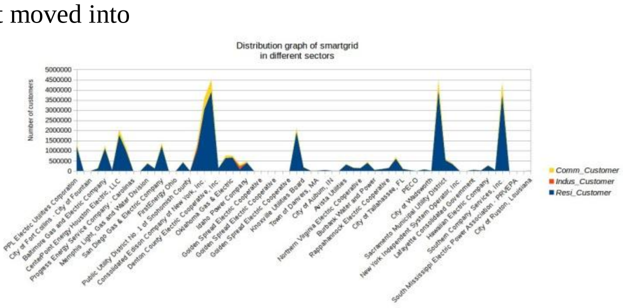

Fig. 4. Distribution of SG in different sectors

HDFS and after some computation performed by it, then begin the job. After several performance analysis it has been observed that this may lead to a significant delays before start of job if the source data is replicated at several locations. As the mappers and reducers were locally distributed into the HDFS system hence the delays may incurred from the intermediate data as they fully dependent on the network bandwidth leads to higher costs. To solve the above mentioned problem, in this paper, We have introduced three architectures LMR, GMR and DMR as we have already discussed in previous section and we have also examined the three different levels of data aggregation according to the workloads at data centers. These are:

- High aggregation
- Zero Aggregation
- Ballooning Data

Here, we gave more emphasis on the size of output data because during the reduce phase there may be a chance of overheads when all-to-all intermediate data computes. In this paper, we further analyzed that the performance of MapReduce operated over widely-distributed data. We have tested the performance over three architecture by varying workload, proposed possible ideas for the use of distributed data, resources, and workloads combining with different architecture according to the experiments performed. Finally we have calculated the performance matrix and distribution of SG in different scenario, as shown in Figure 4.

V. Conclusion

Expanding the cost of energy and the impacts of greenhouse gasses are the most important issues which prompt more consciousness of energy effectiveness of power supply. In the last decades a lots of innovations have been made to build up this effectiveness. This paper outlines different looks into which are done on improving of the energy effectiveness. On the rest step the idea of energy effectiveness and its advantages looked into and afterward by presenting a few advances, their potential applications and advantages are talked about. In addition, we think about What is more, to wrap up that what is required now is a push to build up a coordinated vision for Smart Grid and strong initiative to present this vision on the general population who are capable to get it going.

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