Using Predictive Analysis for optimizing Energy Management Systems

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1. Introduction

"Green Energy is key to our future", the quote is loud and clear. We need to realize the fact that our future existence depends upon how we use renewable energy resources with greater efficiency. We need to create a self-sustained intelligent system that can take smart decision automatically for optimum use of energy resource available.

Power industry has taken many initiatives in this direction by deploying standalone solutions covering either solar, wind or battery storage energy. However an integrated solution having self-intelligence and decision making capability is still lacking. This has been mainly due to limited technology usage and / or non-lucrative business models.

This paper discusses the use of 'Predictive Analysis' integrated with Energy Management System which opens up many new potential possibilities. System uses mathematical analytical algorithms based on machine learning of direct factors i.e. energy resources data and in-direct factors like environment impacting the energy resources and creates energy usage patterns and provides relevant data models. Based on the Geo specific data model analytics, a business logic is build and applied for automatic selection of input energy resource (like main Grid, Dry cell Battery, Solar Photo Voltaic and Diesel fuel), when system should be charging battery, how the operational cost is optimized, carbon footprint reduction etc…

This concept is explained by taking relevant use case in Telecom industry for optimizing cost of Telecom Towers (i.e. Base Transmitting System) wherein migration from a hybrid-source solution (i.e. Grid and Diesel) to multi-source (i.e. Grid, Lithium Ion / Lead Acid Batteries, Solar, Diesel) with EMS controller being remotely updated with appropriate business logic based on machine learning.

2. Need for green initiatives

The ongoing rise in the cost of diesel fuel and other energy sources has resulted in expenditure increase for service providers and consumers. The global trend in reducing our carbon footprint has also necessitated a shift towards the development and adoption of green initiatives.

It is very clear that fossil fuel reserves are finite. Every year we currently consume the equivalent of over 12 billion tonnes of oil in fossil fuels. Crude oil reserves are consuming at the rate of 4 billion tonnes a year [1]. If we carry on at this rate without any increase for our growing population or aspirations, our known oil deposits will be gone by 2050. This data shows cost pressure will increase on every sector where fuel is used as primary resource of energy.

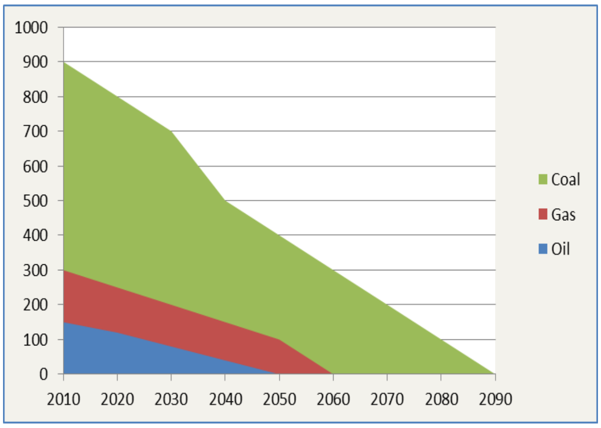


Fig 1.0 Energy reserve vs yearly consumption – Graph

From a regulatory point of view, clean-energy technologies are well supported by the Indian Government's reform and subsidy policies like RAPDRP, JnNURM to improve power supply condition in Generation-Transmission-Distribution sectors and promote renewable energies.

3. Current Limitation in Telecom Industry

Indian telecom industry is largest consumer of diesel consumption, estimated at more than 2.5billion liters a year. This translates to yearly energy expense of approx. Rs 6500 Cr. This corresponding to approx. 5.2Million tonnes of CO_2 emission which is nearly 2-3% of total India Green House Emission (GHG). To overcome the dependency on Diesel, many initiatives were undertaken by Government of India wherein Telecom Regulatory Authority India (TRAI) released in 2011 the Green Telecommunications [2] guidelines followed by its mandate in 2013 [3] that requires telecom companies to use renewable sources of energy to power at least 50% of rural telecom towers and 20% of urban telecom towers by 2015. By 2020, the telecom companies have to convert 75% of rural towers and 33% of urban towers to run on hybrid power. The MNRE's 2013 mandate to convert a minimum of 50,000 towers to solar photovoltaic technology starting was another step towards ensuring compliance for the adoption of clean energy [4].

However, power availability is still a major challenge for telecom towers -

- In Rural areas conventional grid power not available and more than one lakh villages still remain to be electrified
- Wherever grid supply is available, power quality is poor and erratic with power cut of 12 hours a day

- Poor power quality mainly due to
  - Supply interruption
  - Sudden change in voltage
  - Under voltage/over voltage
  - Voltage fluctuation

Due to above limitation, telecom operators necessarily invest in providing back up options via -

- DG Set
  - Transportation, storage, pilferage, high cost of diesel pose major hurdles in operating DG sets.
  - Causes pollution (environmental & noise)
  - Operator depend heavily on diesel generator to power BTS towers.

- Inverter-Battery Systems
  - Low voltage and intermittent supply of electricity renders inverter-battery ineffective and

battery doesn't get fully charged due to unreliable supply of grid power.

- Solar PV / Wind Kit
  - Subsidy from MNRE is only 30% on hardware. Getting the subsidy itself is a long process.
  - Additionally, PV panel needs to be cleaned daily for maximum output.
  - Currently weather information is not considered for optimizing the PV output.

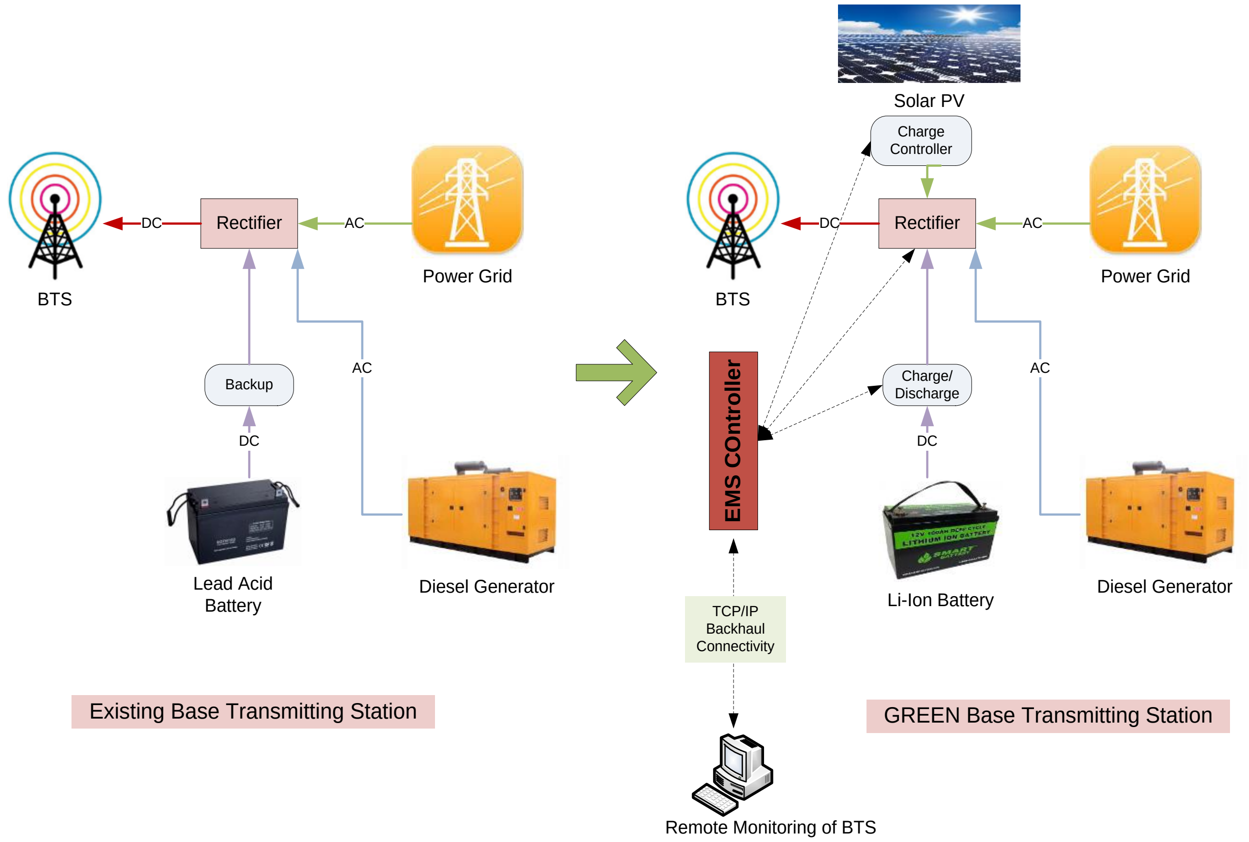
As a result, telecom operators continue to rely on expensive, environmentally-unfriendly diesel fuel to keep their towers running.

From a technology point of view, currently installed BTS Energy Management System (EMS) controller performs priority based switch over between available energy source i.e. Grid / Diesel / PV/ Battery.

This simple priority based switchover can be made more intelligent based on business logic being function of Static inputs (Fuel Cost) Vs Dynamic inputs (Power Outage, Weather Information, Temperature etc…) and Actual Value (Power, Diesel level, Battery charge etc…) Vs Predicted Value (Power Outage prediction, schedule for battery charging, PV output etc….).

A Typical Green BTS with multiple energy sources is shown below in Fig. 2.0

Fig 2.0 Green BTS Architecture



This combination of various inputs and using the same effectively can help reduce the dependency on diesel and CO2 emission.

4. Role of EMS, Renewable and Predictive Analysis

A typical EMS system played a great role with Lithium/Acid battery and renewal energy sources to select the appropriate resource to provide electricity to BTS towers.

The important questions are that given the past power consumption and outage data,

- Can we forecast power outage accurately?
- Can we forecast renewal energy production in next 48 hours?
- Can we provide insight into potential cost savings along with uses of different energy sources?
- Can the system independently decide, on real time basis, which energy source to use and in which proportion?

Though traditional EMS system with renewable energy integration perform some of optimization but there still exist a huge gap between Planned Vs Actual figures.

E.g.: Considering a remote BTS site at Mewa Village, Meerut having following details:

- Avg. power outage: 10hrs daily.
- Before renewable energy integration

o Energy Sources

☐ Grid

☐ DG

o DG Run Hours : 10 - 15hrs

- Post renewable energy integration-

o Energy Sources

☐ Grid

☐ Solar PV kit

☐ LiB Batteries

☐ DG

Now, telecom tower operator shall plan for reducing the DGRH to a minimum during outage and normal operations. Tentative planned run hours -

Energy Source	Planned Run Hours
DG	<5hrs
Solar	5-6hrs
Battery	7-9hrs

However, during the actual day the above figures are meet only up to 40-50%. This is because the optimization planned was based only on historical reports and real time data.

This is where data prediction can help in achieving the planned energy source optimization to its maximum capability by collaborating data across two time lines –Past + Present and predict Future events.

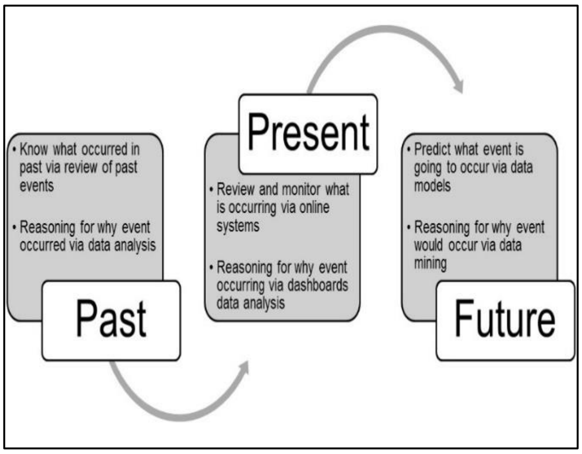


Fig 3.0 Predictive Analysis Framework

A Smart EMS system can be designed to increase the optimization from 40-50% to 80-90% with help of big data predictive analysis engine.

NEC[5] has developed Heterogeneous Mixture Learning technology for predictive analytics for data where multiple patterns exist and representation of data with single equation is difficult to interpret. A new analysis techniques has been used that automate trial-and-error processes that analysts have traditionally had to perform manually in order to discover patterns in analyzed data, namely "partitioning data" based on conditions such as day of the week or weather and "combining factors" that are important in making forecasts. This enables super-large-scale demand forecasting (for example, sales forecasts by store and product, energy demand forecasts, etc.) on millions of analysis targets, something which has been limited by conventional manual techniques.
Previously, data analysts possessing advanced expertise had to manually perform the processes of partitioning data and combining factors. For instance, when forecasting sales in a retail business, an analyst would have to repeatedly perform the data partitioning process based on conditions such as day of the week and weather, in addition to carrying out statistical analysis of sales trends in different store locations. Moreover, when investigating how an important factor combined with a certain product can influence the sales of other types of products, an analyst would have to form and evaluate hypotheses for each product in advance. Please refer Fig 4.0.

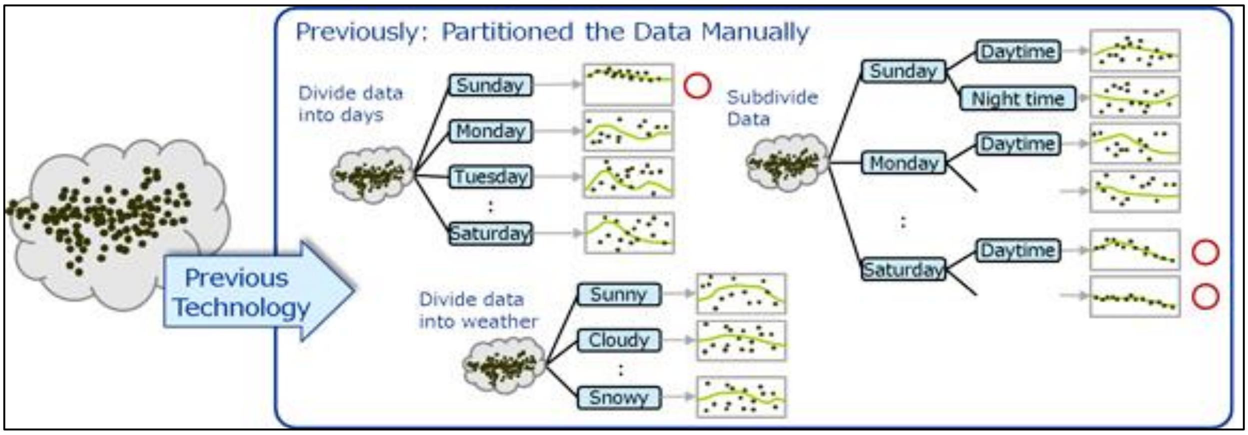


Figure 4.0 Traditional partitioning

Automation of these data partitioning and factor combination processes, has enabled data analysis combining a wide array of conditions where manual analysis ran into limitations, such as forecasting the sales of several million types of products in the distribution field, or forecasting energy demand. Please refer Fig.4.1 and 4.2

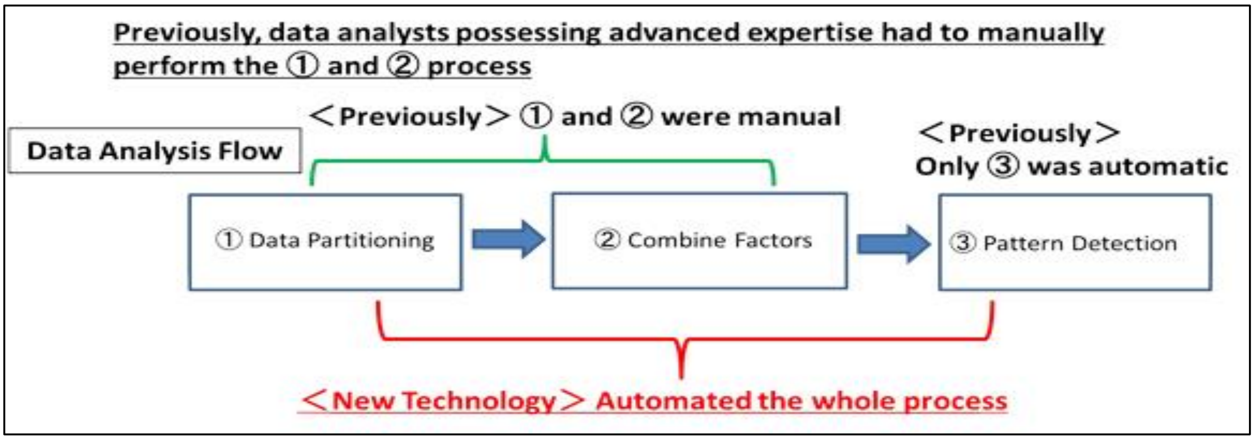


Figure 4.1 Manual to Automated Prediction

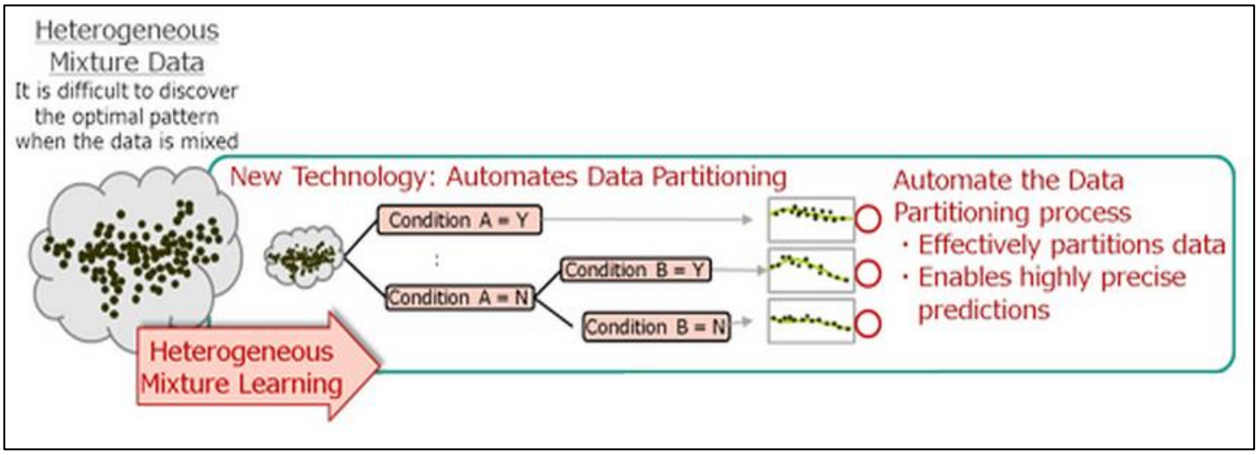


Figure 4.2 Heterogeneous Mixture Data Prediction

By simultaneously searching for multiple patterns hidden in large volumes of data (formulas represented by combinations of multiple factors) and the conditions that establish those patterns, the optimal conditions for partitioning data can be quickly identified from among vast quantities of conditions.

The system automatically identifies the optimum factor combinations needed for prediction and forecasting from among a large volume of candidate factors extracted from data subject to analysis as an interim step in the process described in above.

Applying the machine learning to our current Telecom Tower EMS Use Case, we have come up with two levels of implementation:

Level 1:

1. Collects direct and indirect energy related data from sensors and transmit to EMS Server
2. Performs Machine learning and develop mathematical prediction model and keeps refining automatically
3. Builds business logic based on the model to enable EMS controller to take run time decisions for selecting combination of energy resource in optimum way

Level 2:

Further EMS system can group multiple sites in same geographical area to build collaborative model which will give generic prediction model and can apply for new site at that geo location

A green BTS EMS System is deployed with following units (refer fig 4.3):

1. Sensors units – Data collection from direct energy resources like Diesel, Grid, PV, Wind etc.
2. EMS Controller – Brain of BTS, Controls EMS system & execute business logic
3. EMS Server – Store raw data of direct and indirect energy resources of BTS site. Input the raw data to Analytics Engine get the refined model and update EMS controller and business logic for better optimization.
4. Analytics Engine - Machine learning and develop mathematical prediction model based on the direct and indirect energy resources

Recent research by NEC in hetero mixture machine learning technologies have shown that, give past data it is possible to discover periodic patterns, and consequently predict the outage points and duration of power outages for a BTS station.

During the training phase, past data about power consumption and outages is given to HME algorithm. Also, additional features like weather data, temperature can be given to capture seasonal or weekly trends and based on that can able to predict the renewal energy production for next 48 hours. The HME engine creates a model consisting of mixture of individual regression lines. Even non-linear relationships are approximated by piecewise linear models.

The statistical model, then can applied as software service which can give forecasts for power outages. Initial research suggests that accuracy of up to 95% is possible for next 1 Hr forecast.

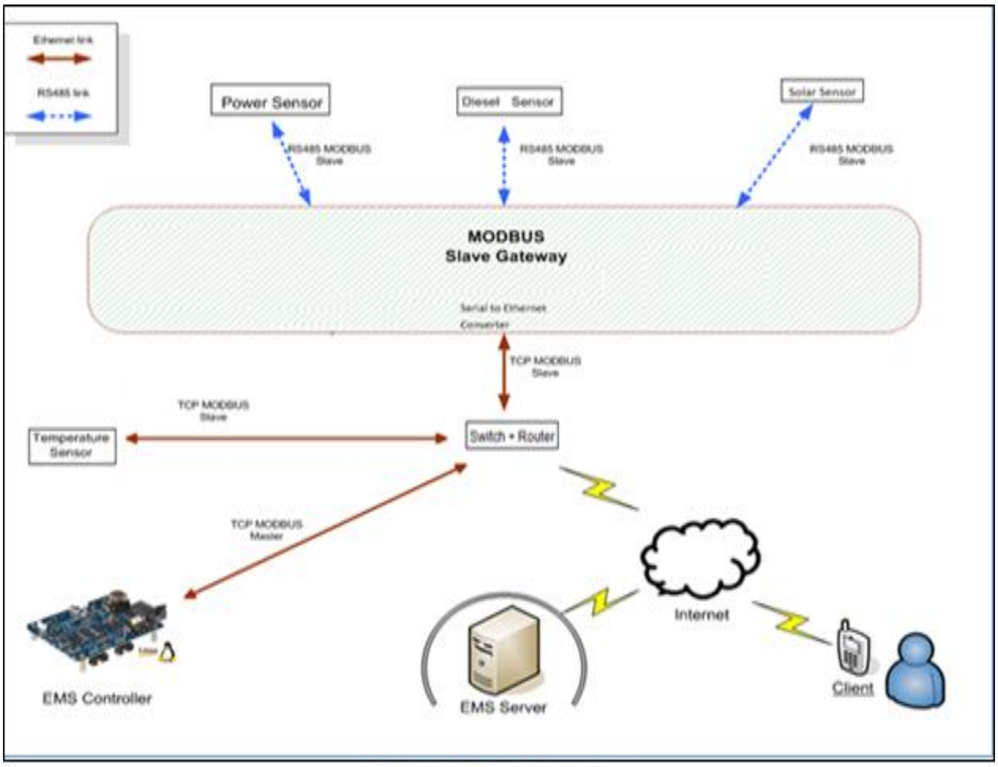


Fig 4.3 : EMS Architecture

Similar to the hourly outage prediction, we can use the prediction engine to predict the

- Load profiling of different energy inputs

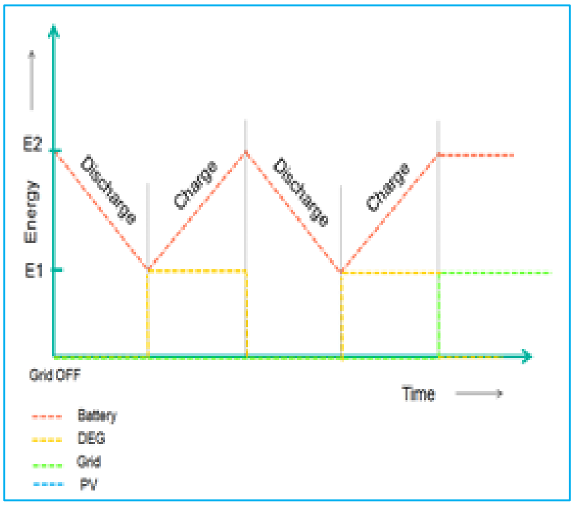


Fig 5.0 Predictive Load Profiling

- Diesel cost and GHG emission saving
- System breakdown etc…

Currently the prediction engines uses various parameters for data modelling as shown in table no

1.

The parameters are combination of (direct, indirect) + (static, dynamic) values. It is to be noted that telecom towers need to have a tie up with –

- Utilities to get scheduled power shedding information. However in absence of it, the predictive engine would be able to generate this data based on the actual power-cut in past. In case
- Weather forecasting engine for regular weather information

S.No	Device type	Input Type	Parameters Measured
1	Battery	Direct + Dynamic	Status (Charge/Discharge/Idle)
			SOC %
			Energy (Wh)
			SOH %
			Temperature in Battery (°C)
			Power in Battery (W)
			Voltage in Battery (V)
			Current in Battery (A)
			Temperature outside Battery (°C)
			Discharge Energy (Wh)
			Charge Energy(Wh)
2	DG	Direct + Dynamic	Status (On/Off)
			Power (W)
			Voltage (V)
			Current (A)
			Residual fuel (Litre)
3	Grid	Direct + Dynamic	Status (Outage/No Outage)
			Power (W)
			Voltage (V)
			Current (A)
4	BTS Load	Direct + Dynamic	Power (W)
			Voltage (V)
			Current (A)
5	Cooling AC Unit	Direct + Dynamic	Apparent Power - R, Y, B
			Voltage - R, Y, B
			Current - R, Y, B
			Power Factor - R, Y, B, Total
6	PV	Direct + Dynamic	Power (W)
			Voltage (V)
			Current (A)
			Solar Radiation W/m²
			Temperature (°C)
7	Temperature Sensor	Indirect + Dynamic	Outside temperature (°C)
8	Grid Fuel Cost	Direct + Static	Cost Per kWh
9	Diesel Fuel Cost	Direct + Static	Cost Per litre
10	Solar Energy generation in next 48 hours	Direct + Dynamic	Units in kWh
11	Power cut predication in next 48 hours	Direct + Dynamic	In Hours:Mins
12	Published planned power cut by grid companies	Direct + Static	In Hours:Mins

Table 1.0 Prediction Engine Inputs

5. Use case

BSNL, an Indian telecom operator, and NEDO, Japan's technology firm, are conducting joint discussions on utilizing solar energy for telecom network.

Chief officials of both organizations held a talk on the possibilities of substituting conventional energy with solar resources. This initiative comes after a directive from the Prime Minister to initiate efforts on Carbon reduction. [6]

As described in section 4, Level 1 (EMS deployment and data collection) started in various site in India. Some snapshots are given below of one of the site:

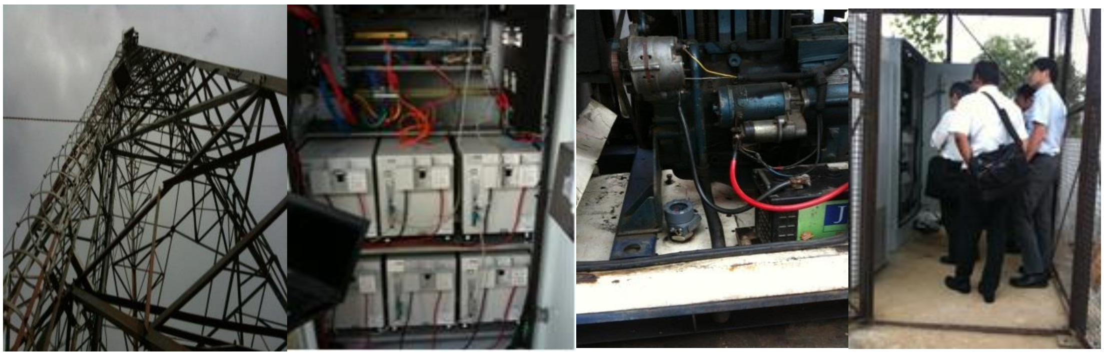


Fig 6.0 Site Installation Pictures

From a cost benefits perspective, already it is proven that usage of renewable energy source (Solar, Battery) reduces the dependency on diesel and greenhouse gases as shown below from a published report [7]

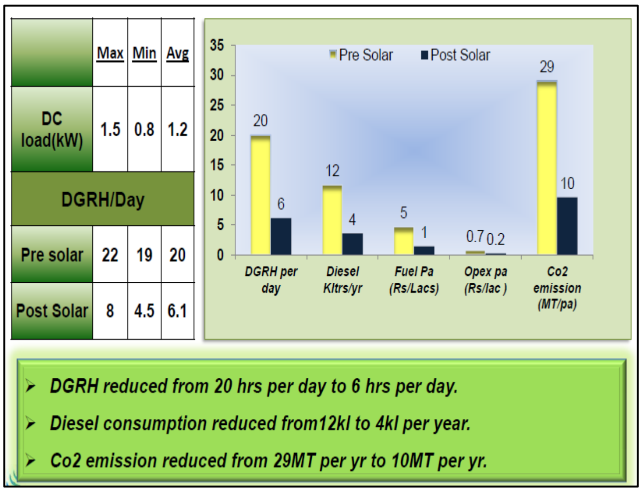


Fig 7.0 Reduced Diesel Consumption

It is expected that by usage of Predictive Analysis (HME) the gross savings shall be further increased in terms of less diesel usage and GHG emissions.

Currently work is in progress for 20 BTS sites in India and cost saving results a/c Predictive

Analysis shall be published post completion.

6. Benefits

Few of the benefits of this predictive analysis can be listed as below –

- Early warning system helps in better planning and response of service provider
- Higher uptime (99.9%) and compliance to Service Level Agreement (SLA)
- Improved revenue cash flow due to intelligent switchover between available energy sources

o Reduced diesel consumption

o More carbon credits

o Usage of efficient Lithium Ion battery with better performance over traditional lead acid battery

- Flexibility to add more renewable solutions

7. Summary

Globally, predictive analysis is already been used across different industry segments like:

- Smart Healthcare
- Homeland Security
- Traffic Control
- Retail
- Trading Analytics
- Online e-commerce
- Telecom etc…

In developed countries Smart Grid arena the focus is on big data mining and predictive analysis to provide useful data to utilities to improve service efficiency and cash-flow.

Indian Smart Grid activities current focus is on reliable data acquisition via different open communication technologies. Once data flow gets stabilized, the focus would automatically shift on big data mining in line with developed countries.

Hence it is imperative that we start exploring how available predictive analysis framework can be extended to green Initiatives like Smart Buildings, Energy Storage Systems, AMI, Smart Metering, Demand Response etc.

8. References

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