EXPLORATORY PROJECT REPORT

DEPARTMENT OF ELECTRICAL ENGG.

IIT BHU (VARANASI)

TOPIC:- ENERGY CONSUMPTION AND MICROGRID

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AIM :- Data analysis of energy consumption in a community and to use predicted statistics to convert a simple Microgrid to a Smart Microgrid, to reduce energy losses.

ELECTRICAL GRID : An electrical grid, electric grid or power grid, is an interconnected network for delivering electricity from producers to consumersElectrical grids vary in size from covering a single building through *national grids* (which cover whole countries) to *transnational grids* (which can cross continents).

Power stations connected to grids are often located near energy resources such as a source of fuel or to take advantage of renewable energy resources, and away from heavily-populated areas. A bulk-power transmission network is therefore used to move the power long distances, sometimes across international boundaries, until it reaches its wholesale customer (usually the organisation that owns the local electric power distribution network). The electric power is therefore stepped up to a high voltage for the electric power transmission system. On arrival at a substation, the power will be stepped down from a transmission level voltage to a distribution-level voltage. As it exits the substation, it enters the distribution wiring. Finally, upon arrival at the service location, the power is stepped down again from the distribution voltage to the required service voltage(s).

CHALLENGES TO GRID SYSTEM:-

1. Dependence on Natural Gas:- Because of limited pipeline capacity and few delivery points for liquefied natural gas (LNG) into the region, fuel availability to electric generators is constrained on the coldest days when firm supply goes first to space heating.

2. Voltage Control :-Voltage regulation is a critical aspect of utility reliability. State regulations require all utilities to maintain steady state voltage with set limits, which has traditionally been achieved using capacitors, load tap changers on substation transformers

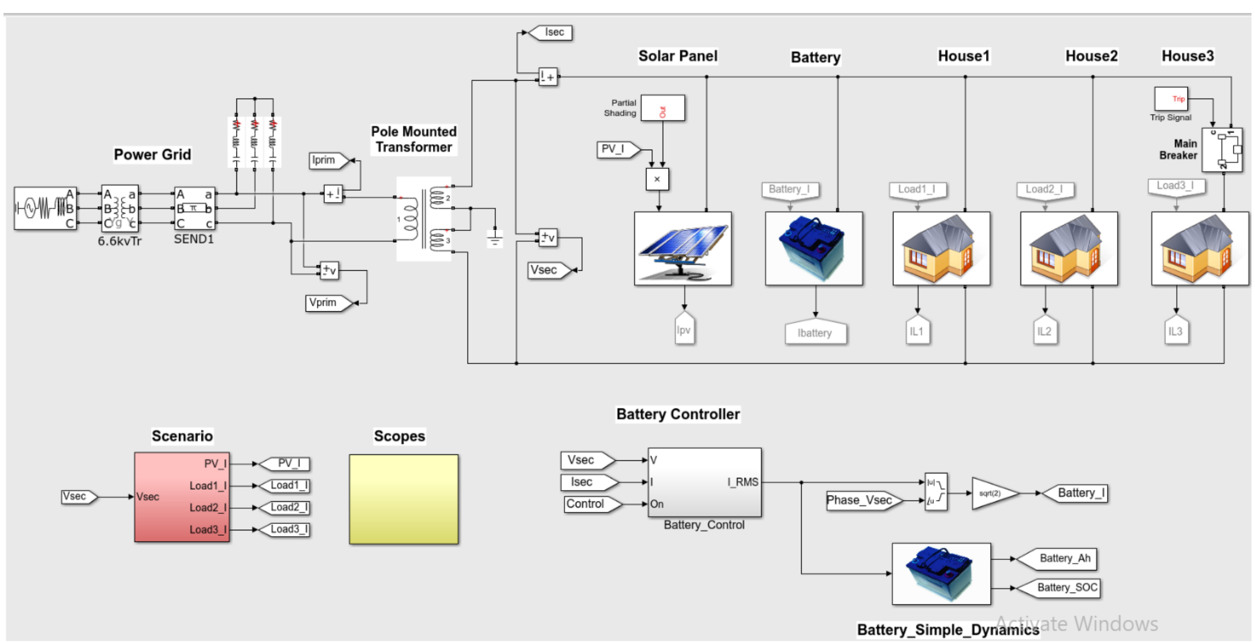
3. Evolution and Growth of Storage:-The characteristics of the various battery storage options, and therefore their value streams, vary greatly. Some batteries achieve high output for a short duration; others are more effective for large amounts of storage delivered over a long time

4. **Changing Daily Load Curves:-** High renewable penetration has fundamentally changed the timing of daily peaks. Traditionally, load peaked around 2 p.m. when commercial energy demand reached its highest point.loads used to ramp up in the morning, peak in mid-afternoon, and drop gradually, on a sunny day, mid-day loads drop to the bottom of the duck’s belly, and then rise to their daily peak when the sun goes down.

MICROGRID:

The integration between electricity sourced from PLN and electricity sourced from renewable energy needs to be managed so that the use of renewable energy in supporting household electricity needs is more effective. In order for its utilization to be effective, it is necessary to develop a control system that regulates time or detects events so that it can properly control the use of PLN electricity and renewable energy.

Smart grid enables integration between conventional power plants that rely on fossil fuels (coal and oil) and non-fossil power plants that utilize renewable energy (solar, wind, water, etc.). Through this smart grid, coordination and automation in generating energy will occur. For example, when a solar power plant whose electricity production depends on sunlight conditions, the smart grid must be able to respond to supply shortages from solar power plants from other sources. The presence of smart grid will certainly reduce dependence on the use of fossil fuels so that it can reduce pollution and operational costs. Integration of energy sources allows the spread of stations to build up not only on the provider side but also on consumers. In the given figure you can see that Renewable energy sources use solar energy and are integrated with the PLN electricity network. Solar energy is converted into electrical energy using solar panels (photovoltaic) in the form of direct current (DC). Furthermore, it is converted into AC (alternating current) using an inverter to be used directly by the load. The energy management system is used to regulate and coordinate the energy supply process both from the supply of PLN electricity and electricity from solar energy.



SMART METER:- A smart meter is an electronic device that records information such as consumption of electric energy, voltage levels, current, and power factor. Smart meters communicate the information to the consumer for greater clarity of consumption behavior, and electricity suppliers for system monitoring and customer billing. Smart meters typically record energy near real-time, and report regularly, short intervals throughout the day.[7] Smart meters enable two-way communication between the meter and the central system.

Such an advanced metering infrastructure (AMI) differs from automatic meter reading (AMR) in that it enables two-way communication between the meter and the supplier. Communications from the meter to the network may be wireless, or via fixed wired connections such as power line carrier (PLC).

Smart metering offers potential benefits to customers. These include, a) an end to estimated bills, which are a major source of complaints about many customers b) a tool to help consumers better manage their energy purchases—smart meters with a display outside their homes could provide up-to-date information on gas and electricity consumption and in doing so help people to manage their energy use and reduce their energy bills. Electricity pricing usually peaks at certain predictable times of the day and the season. In particular, if generation is constrained, prices can rise if power from other jurisdictions or more costly generation is brought online

APPROACH OF PROJECT:-

1. Due to the challenges faced in operating microgrids, due to variable daily usage of electricity, we have developed a **Machine learning model that trains on past data of Electricity consumption and aims to predict a future trend**. This can help in improving a microgrid and convert it into a **Smart Microgrid**.
2. Data collected is available open source from UK Power Networks.
3. Out of several features available, we used a few relevant ones. This is decided by observing the correlation between features and target values.

Features used:

1. Tempreature
2. Humidity
3. Windspeed
4. UV index
5. Dew Point

Next, we train the model using the ARIMA model and fit it into an LSTM model.

The model can then be used to make future Electricity consumption, with very little degree of error.

The data used in this Exploratory Project is obtained from the London data store, available on kaggle.

Link to source data:-

Smart meters in London

Link to Model that predicts: -

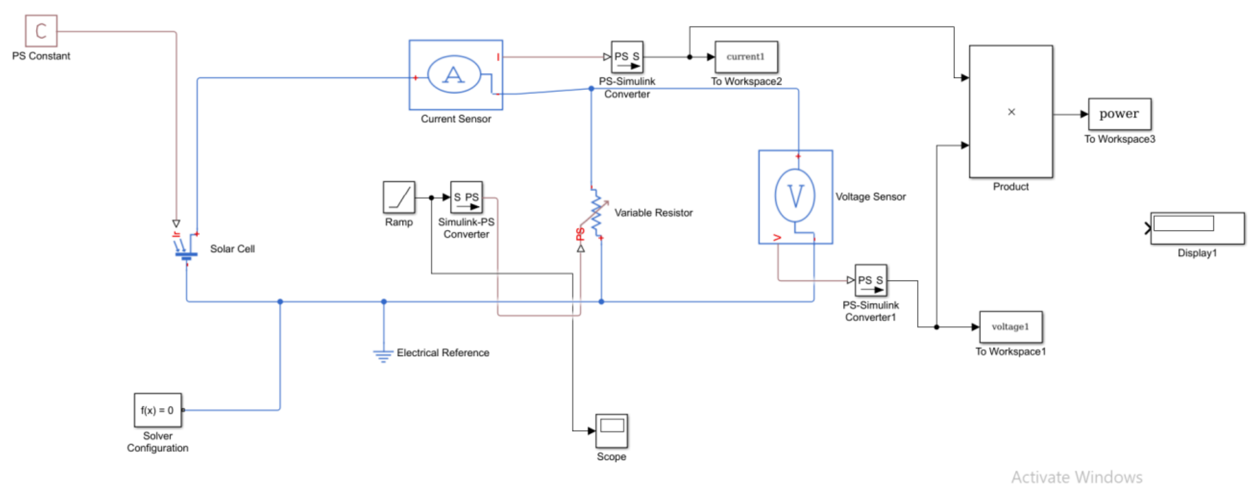
https://github.com/sahiljain200010/ExploratoryProject

Solar Cell

The storage battery is controlled by a battery controller. It absorbs surplus power when there is excess energy in the micro-network, and provides additional power if there is a power shortage in the micro-network. Three ordinary houses consume energy (maximum of 2.5 kW) as electric charges.

The micro-array is connected to the power network via a transformer mounted on a post which lowers the voltage of 6.6 kV to 200 V.

SIMULATION:-

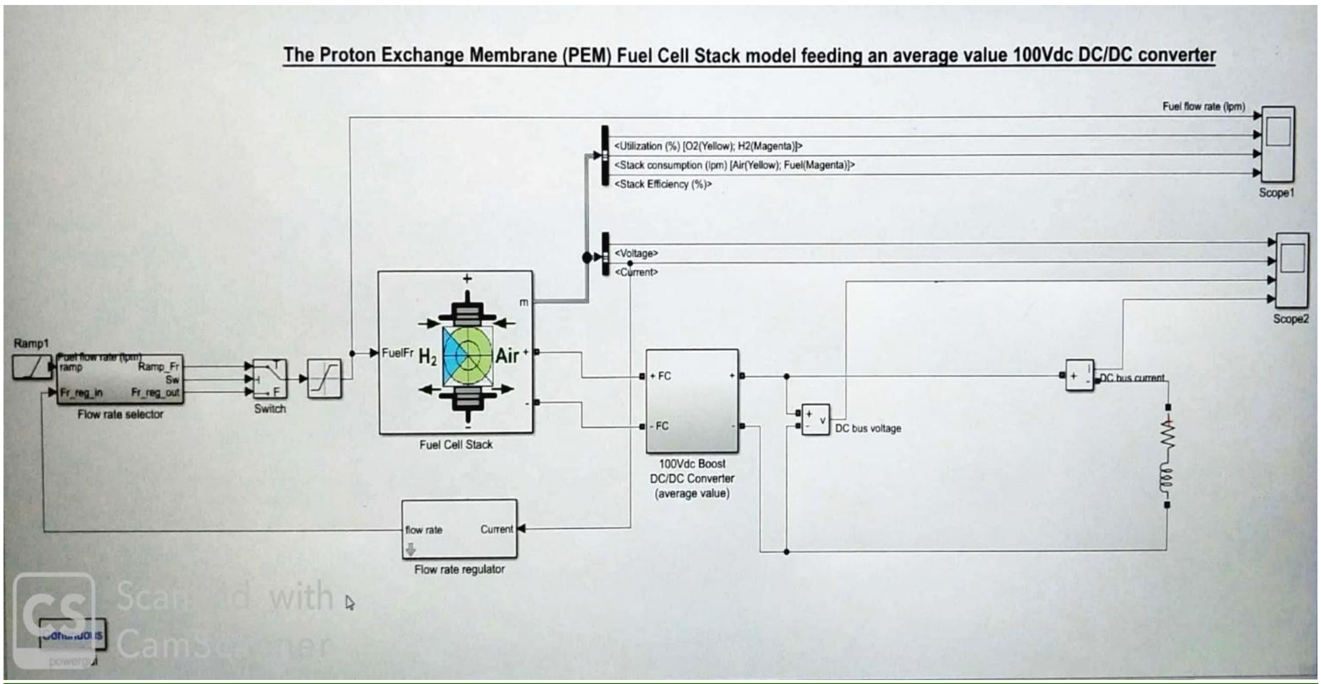


According to given data, the peak comes at 14h to 15h.

As a typical load change in ordinary houses, the amount of electric power load reaches peak consumption at 9h (6,500 W), 19h, and 22h (7,500 W). From 0h to 12h and from 18h to 24h, battery control is performed by the battery controller. The battery control performs tracking control of the current so that active power which flows into system power from the secondary side of the pole transformer is set to 0. Then, the active power of the secondary side of the pole-mounted transformer is always around zero. The storage battery supplies the insufficient current when the power of the micro-grid is insufficient and absorbs surplus current from the micro-grid when its power exceeds the electric load.battery are not performed by the battery controller. When there is a power shortage in the microgrid, the system power supplies insufficient power. When there is surplus power in the micro-grid, surplus power is returned to the system power.

FUEL CELL

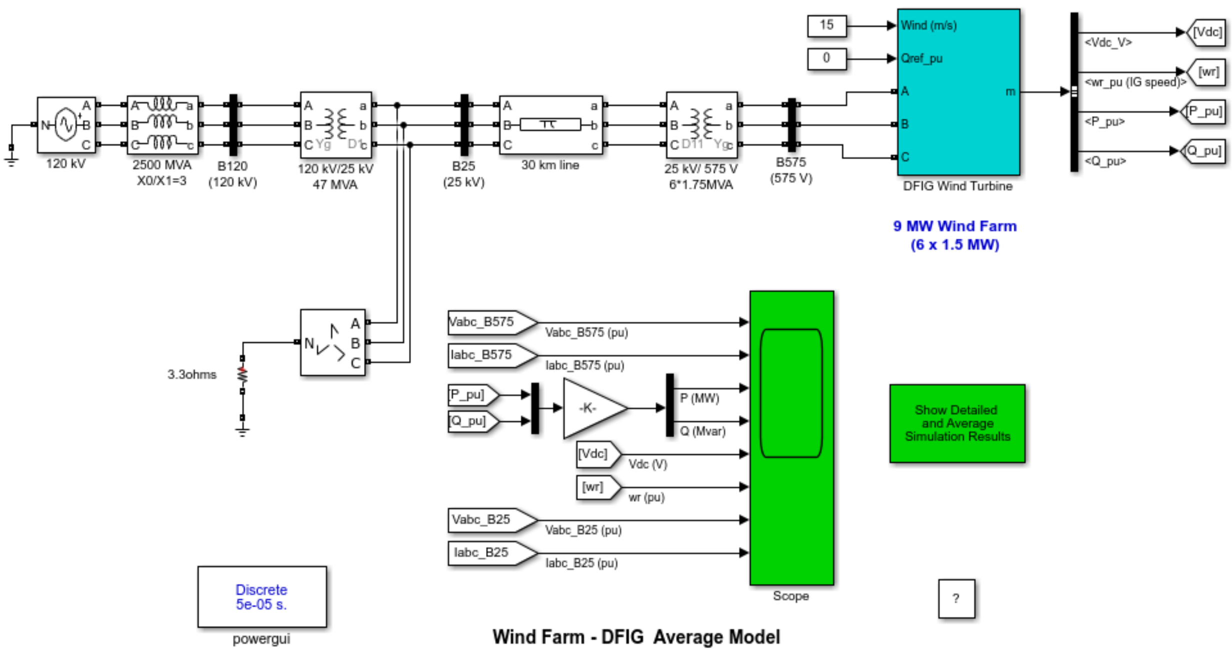
In a Grid Connected Fuel Cell (GCFC) system, the integration of Fuel Cell stacks to the grid has to meet performance parameters related to power quality, reliability and safety aspects. These functional requirements related to integration and control requires a power conditioning unit (PCU) to maintain defined performance parameters. DC-DC boost converter and current-controlled voltage source converter (VSC) are used as PCU and control of VSC is based on power balance control theory(PBCT)



.**<u>SIMULATION-</u>**

A Proton exchange membrane(PEM) fuel cell stack model feeding an average value 11Vdc DC/DC converter is simulated, analysed and discussed. The system prototype model is designed in MATLAB/ SIMULINK to investigate the response of the interconnected components i.e. fuel cell stack, boost converter. The simulation results show that fuel cell stack voltage decreases gradually with the increase in fuel cell current and power. The stack voltage, current, and power take approx. 5 sec to reach their steady-state values. The slow response of fuel cell is due to the slow chemical reactions of gasses in the cells. This PEM system can be used as a power source in a distributed generation system.

Wind Generation System



Wind power or **wind energy** is the use of wind to provide mechanical power through the wind turbines to turn electric generators. Wind power is sustainable and renewable energy.Wind farms consist of many individual wind turbines, which are connected to the electric power transmission network. An estimate of the annual energy output from a wind turbine (in kilowatt-hours per year) is the best way to determine whether it and the tower will produce enough electricity to meet your needs.

SIMULATION:-

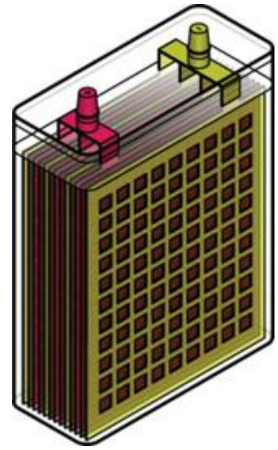
In this, we observed the steady-state operation of the DFIG and its dynamic response to voltage sag resulting from a remote fault on the 120-kV system. Open the "120 kV" block modelling the voltage source and see how a six-cycle 0.5 pu voltage drop is programmed at t=0.03 s

Initially, the DFIG wind farm produces 9 MW. The corresponding turbine speed is 1.2 pu of generator synchronous speed. The DC voltage is regulated at 1150 V and reactive power is kept at 0 Mvar. At t=0.03 s the positive-sequence voltage suddenly drops to 0.5 p.u. causing an oscillation on the DC bus voltage and on the DFIG output power. During the voltage sag the control system tries to regulate DC voltage and reactive power at their set points (1150 V, 0 Mvar). The system recovers in approximately 4 cycles.

Lead-Acid Batteries

Approximately 70% of lead-acid batteries are used for vehicles, 21% for communications, and 4% for other applications.

A high voltage can be achieved by simply connecting lead-acid battery cells in series. Each lead-acid cell, with a 2 V voltage, is made from a spongy pure lead cathode, a lead dioxide anode as well as a 20–40% solution of sulfuric acid that acts as an electrolyte. When the battery is discharging, a chemical reaction allows conduction between the anode and the cathode to generate electricity.

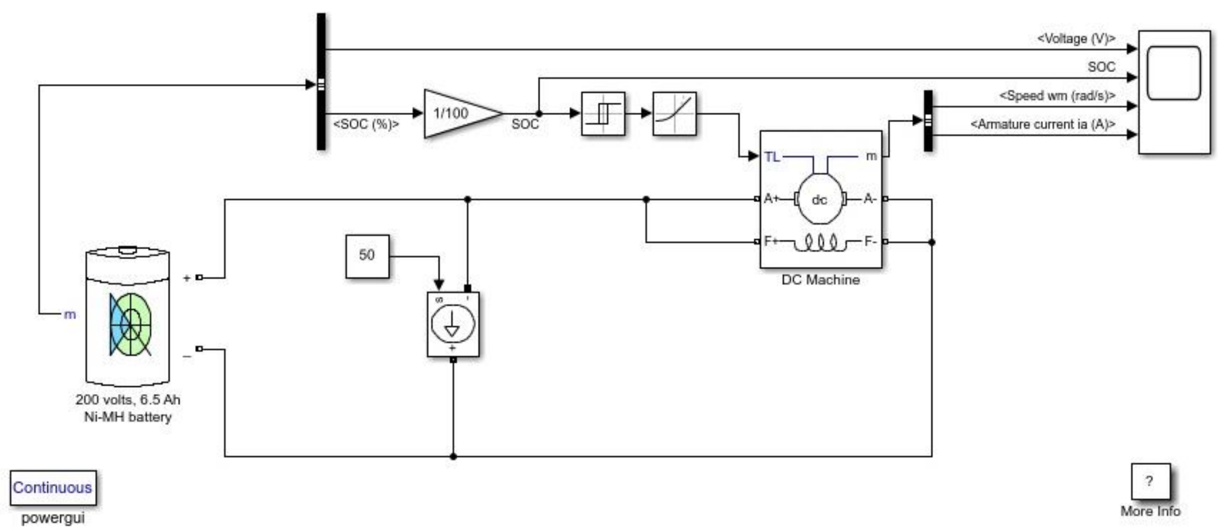


LEAD BATTERY IN SMART GRID:-

Lead batteries are an essential part of successful renewable energy installations for remote communities, which are necessary for sustainable development and many companies are active in this area. More localities can exploit the benefits of reliable, low-cost electricity supplies thus assuring future growth. Also, the technology is improving all the time. Members of the Consortium for Battery Innovation, which includes battery companies from around the globe, are supporting significant new research plans, resulting in a significant leap in performance.

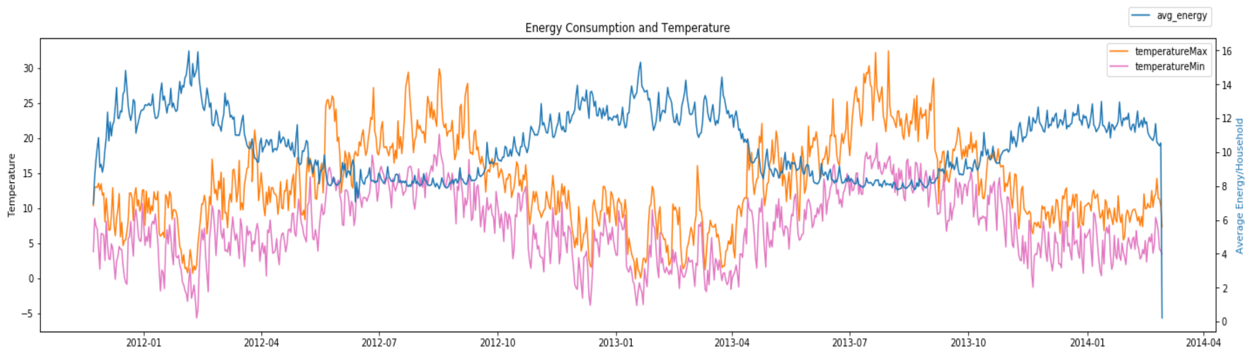
<u>Simulation -</u>

The following is a simulation of a generic Lead-Acid Battery in SIMULINK.-



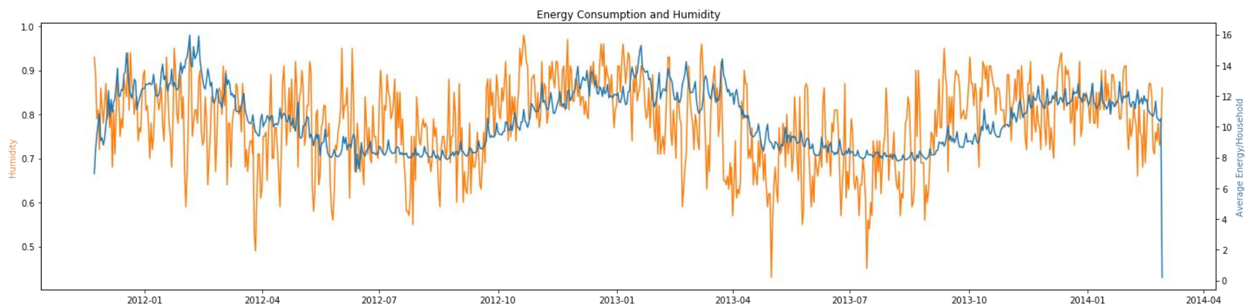
Correlations:

1. Energy used - Temperature:

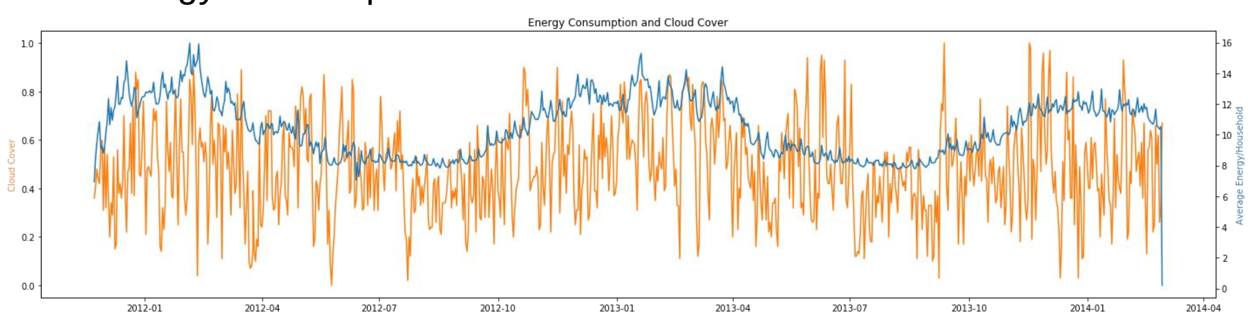


It can be clearly interpreted that Energy consumption is inversely related to temperature of the day.

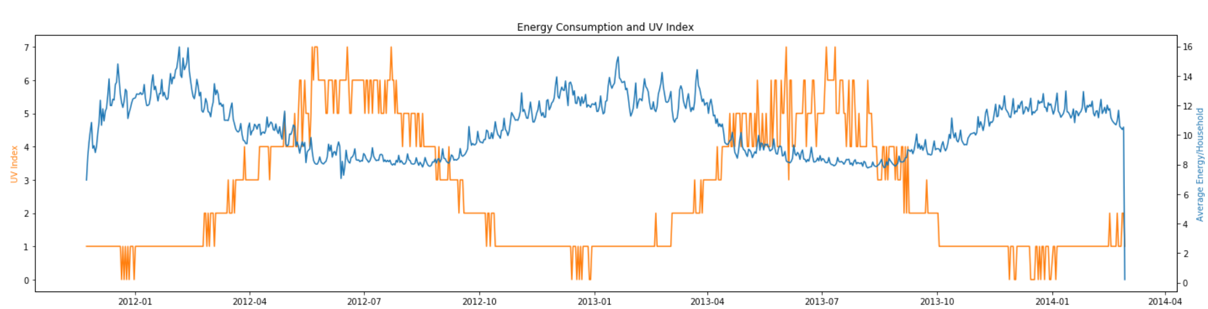
2. Energy Consumption - Humidity:



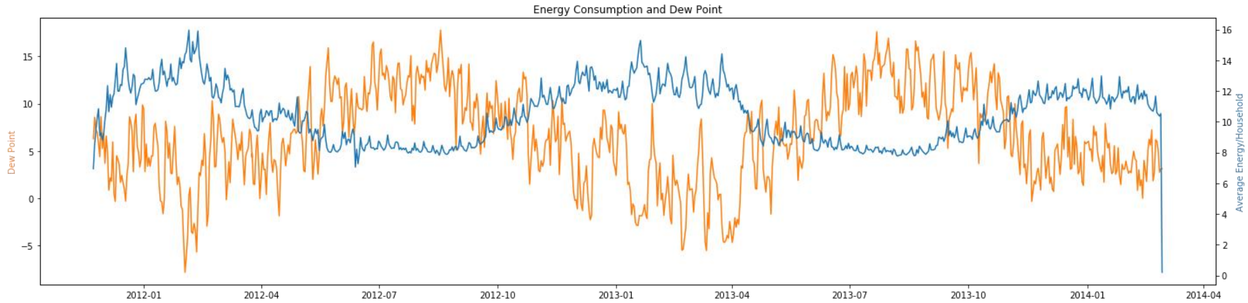
3. Energy Consumption - Cloud Cover:



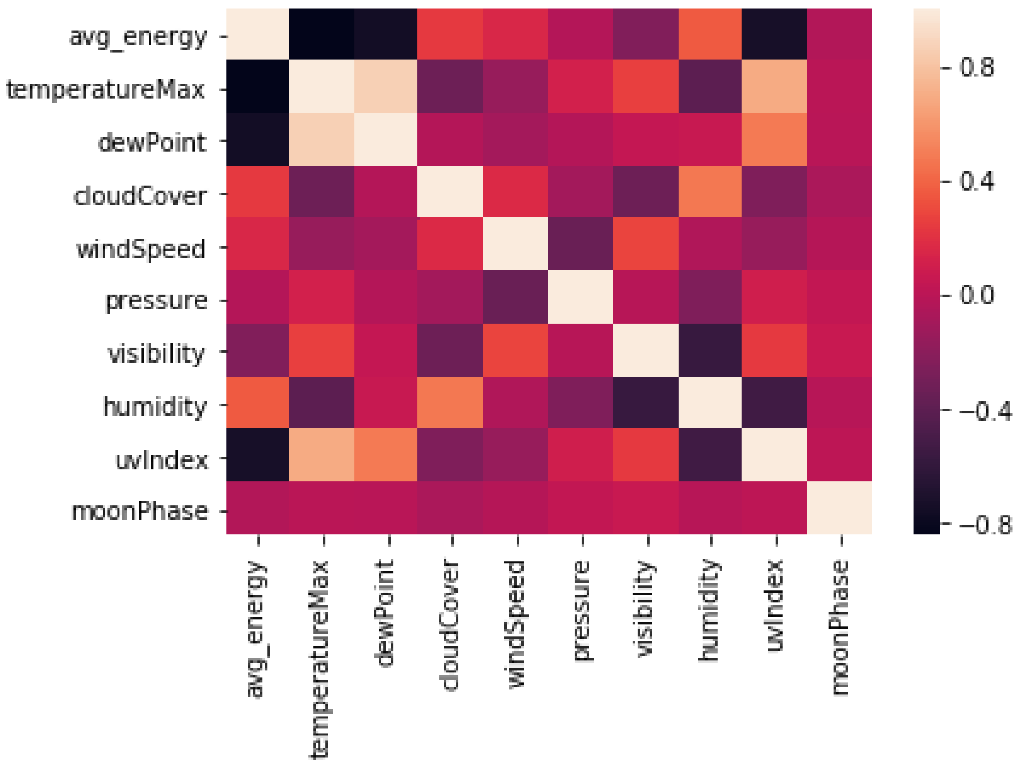
4. Energy Consumption - UV index:



5. Energy Consumption - Dew Point:



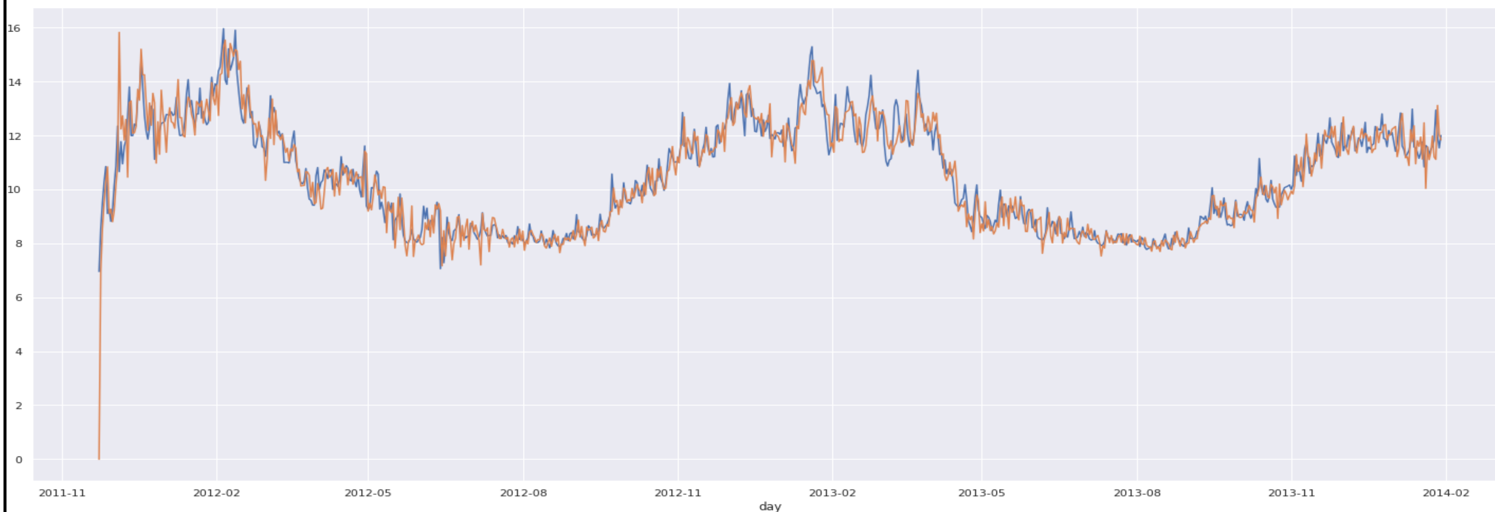
Correlation Heatmap:-



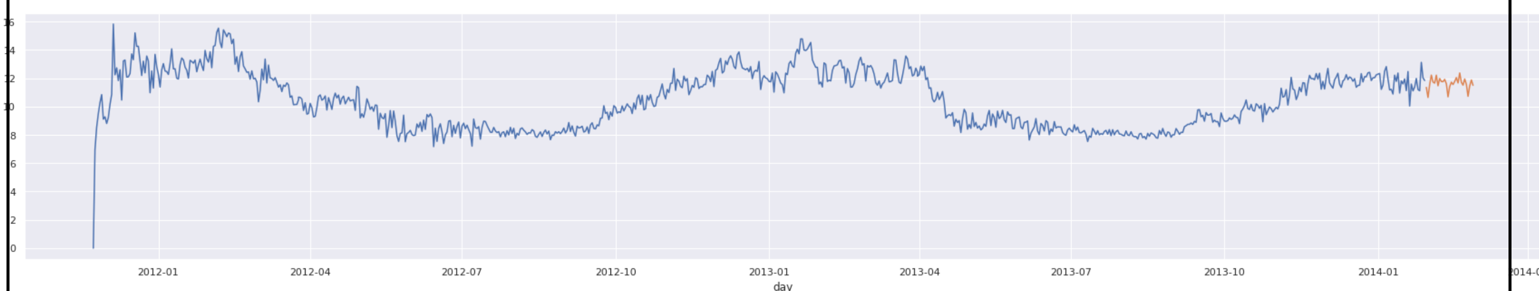
Trained Model Makes Predictions

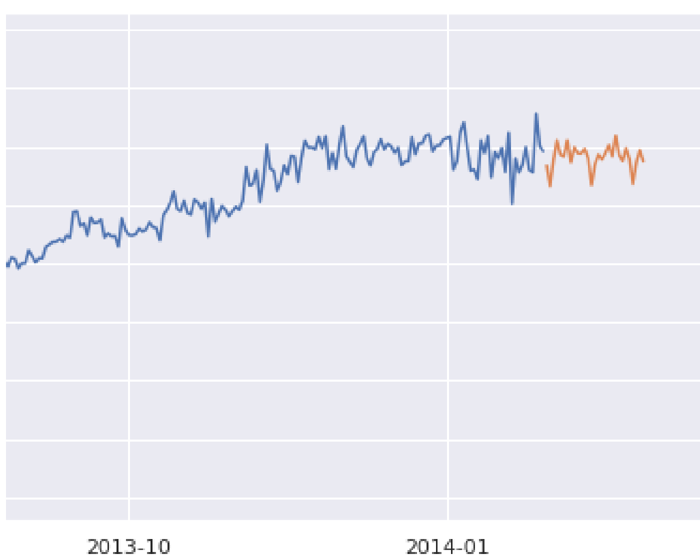
Based on Data of Weather(Temperature, UV index, Humidity) and Holiday index, we train the stats-model SARIMAX.

Model-training:



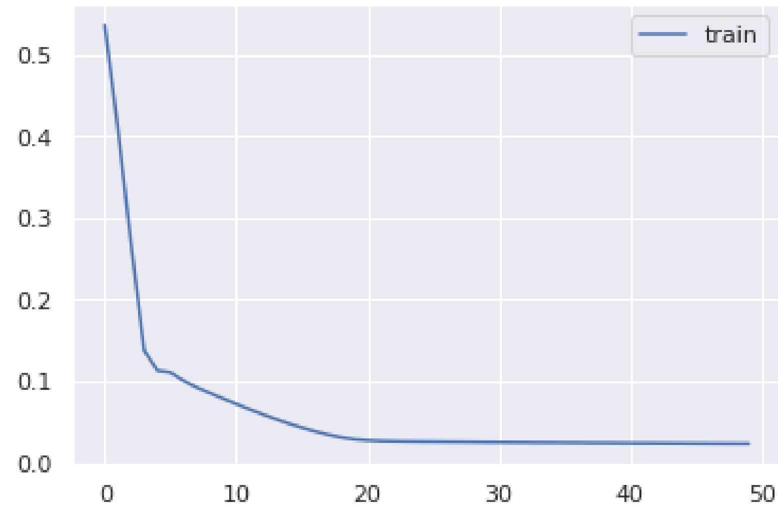
Model-Prediction:



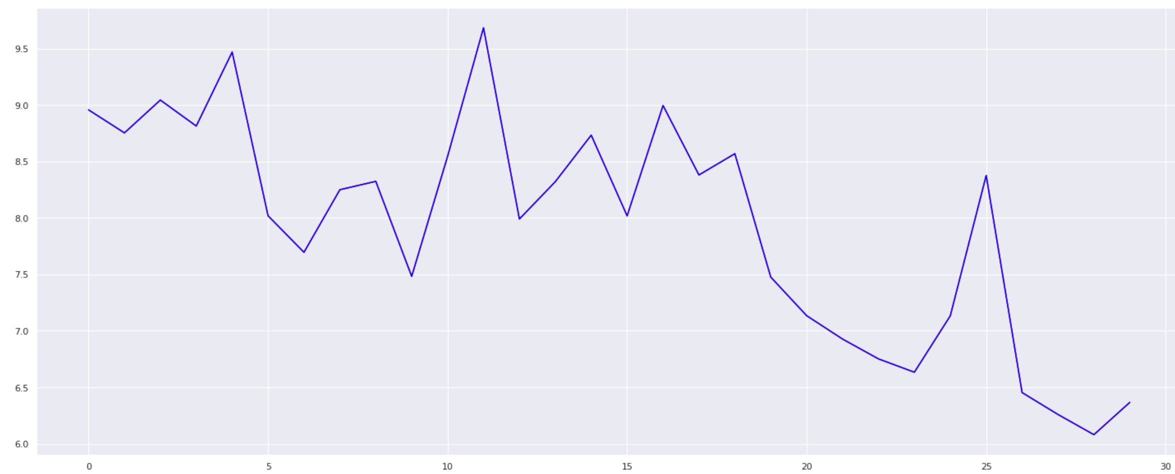


Accuracy of Model:

On multiple iterations of the algorithm epochs, we observe that loss value or the **Error decreases**



Error % in predicted values:



RESULT AND CONCLUSION

The plot of predicted values of Electricity consumption shows that the Machine Learning model might be doing fairly well. This is confirmed by the plot for the % error which can be clearly seen to be going down. The model fares on a good enough accuracy score of ~93.5%-93%.

This model can now be used for a smart microgrid and reduce large amounts of electrical energy wastage.

Applying these kind of models on large scales can significantly reduce loss in energy as well as prevent faults in grids due to large fluctuations in demand. It must be made sure that every model uses local data to train because Electricity consumption trend may vary from region to region.