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E-MOBILITY INFRA LOAD ASSIST, PREDICTOR AND BALANCER USING MULTI FUSION ALGORITHM

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Abstract - *An electric vehicle, also called an EV, uses one or more electric motors or traction motors for propulsion. An electric vehicle charging station is an element in an infrastructure that supplies this electric energy for the recharging of plug-in electric vehicles—including electric cars, neighborhood electric vehicles, and plug-in hybrids. With the upcoming increase in demand for these Electronic Vehicles, the E-Charging Operations (equivalent to today's petrol operator) will be needing a Big Data approach to ensure their customers (end-users) satisfaction and optimal utilization of the E-Charging stations. Based on a data-centric approach the operator can offer dynamic pricing at stipulated times and manage peak demand accordingly. This paper approaches these with an algorithm that predicts the demand power figures of each charging station per hour using Time Series Analysis and balances the load between each charging station in real-time. If more than enough energy is being produced or consumed, they are to be redistributed to balance the load. The entities involved are Station Masters and E-Vehicle owners. The later conditions are as if, the demand for charging is greater than the power they hold or the station runs out of power. And if a charging station holds an excess amount of power or the demand for the day is below the predicted values. To resolve this situation a separate algorithm is formulated that handles the power distribution process in run time.*

***Key Words*: Time series analysis, ARIMA model, Load balancer, Fault Detector, Demand Prediction**

1. INTRODUCTION

In the coming decade, the transport medium will gradually shift towards electric power as the major energy fuel source to run vehicles. Thereby existing petrol stations will be replaced by electric charging stations providing electric power for vehicles. By the upcoming increase in electric charging stations, the distribution of electrical power [1] to each charging station from the powerhouse is a tangled process. Electricity cannot be stored as that of petroleum fuels and the demand for fuel is irregular. Electric power will be dispatched from the powerhouse on a regular basis. Each charging station retrieves a fixed amount of electric power. The problem is described as follows. If a charging station requires an excessive amount of power, or the daily retrieved power may not meet the daily demand the charging stations may shut down until the electric power to the station is re-transmitted. Alongside if the demand for a particular charging station is below the allotted amount of power the excess power at that station is wasted. This paper tackles these in effects considering the transmission from power stations and the irregular demand for fuel refills.

To resolve this problem a rational approach is maintained. First the system predicts the energy demand of each charging station for each day based on a previous data set using TIME SERIES ANALYSIS algorithm [5]. Then the electric power distributed to each charging station will be based on the predicted demand values. Each station gets its load based on the demand on a particular day. An algorithm for predicting the demand using time series analysis is formulated. Second, the running of each charging station is monitored in real-time. Each charging station is connected to each other region wise. Each charging station has a monitoring application that collects real-time inputs and outputs.

The later process is to distribute power in real-time. Each station initially has an amount of power distributed based on the predicted requirement for each day. The later conditions following are If the demand for charging is greater than the power they hold or the station runs out of power. And if a charging station holds an excess amount of power or the demand for the day is below the predicted values [2]. To resolve this situation a separate algorithm is formulated which handles the power distribution process in run time.

The charging stations are connected to each other in a network. The specified algorithm redistribute power in real-time in the connected network. Each charging station in the network is considered as a node and each station is grouped as region-wise. A map-based grouping of regions is performed. Each node exits in a region on the map. The algorithm performs the following operations. If a station runs out of power the algorithm runs and searches for a charging station that has excess power in a particular region and redistributes power from the station to the station in demand. Hence the algorithm manages the power distribution of the entire system.

From the end-users view which is the customer who consumes electric power for their vehicles gets a real-time application with a map that shows the distance to the next charging station. The application considers the following constraints in deciding the distance to the nearest charging station, that is the traffic at the particular region, the availability of power at a station etc. Both the end user application and the charging station operations are based on a common server model. End-user application and charging station operations are both synchronized based on the server.

2. TIME SERIES ANALYSIS

Time series is a set of observations taken at specified times usually at equal intervals. It is used to predict future values based on previously observed values. The same is used in places for business forecasting, understand past behavior and evaluate current accomplishment. Time series analysis has only one variable i.e. Time and its data can be used to extract meaningful statistics and other characteristics.

2.1 Components

The different components of Time Series Analysis consist of the Trend, Seasonality, Irregularity, Cyclic Behavior. The trend is a movement to relatively higher or lower values over a long period of time. So, when the time series analysis shows a general pattern that is upward it is called uptrend, a lower pattern then as low trend and if no trend then is called horizontal trend or stationary trend. Seasonality is upward or downward swings but is different as it's repeating a repeating pattern within a fixed period. Irregularity or noise are erratic in nature, unsystematic as residual. Happens for a short period of time are non-repeating. Cyclic is repeating up and down movements. Time Series has a particular behavior over time that there is a high probability it will follow the same in the future as shown in fig 1. Time Series requires the data to be stationary. Most of the models work on the assumption that the time series is stationary. But if it has a particular behavior over time there is a high probability that it will have to follow the same in the future. The theories and formulas related to stationarity series are more mature and easier to implement as compared to non-stationary series. Stationarity has a very strict criterion. It should have a constant mean in accordance with time. It should have a constant variant, equal at different time intervals and it should be auto co-variant. Let's take a time T and previous times are T-1 and T-2. So, the values at T, T-1, and T-2 should not have any correlation with each other. When these three are met then the series is stationary

2.2 ARIMA model

ARIMA or 'Auto Regressive Integrated Moving Average' is a class of models that provides a given time series based on its Fig. 1. Trend and Seasonality own past values. Any 'non-seasonal' time series that exhibits patterns and is not a random white noise can be modeled with ARIMA models. An ARIMA model is characterized by 3 terms: p, d, q; where, p is the order of the AR term; q is the order of the MA term; d is

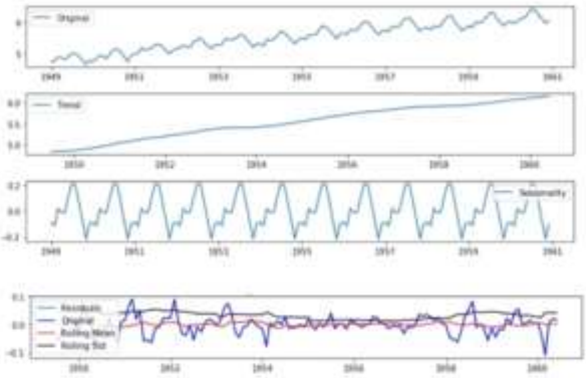

Fig -1: Trend and Seasonality

The number of differencing required to make the time series stationary.

A pure Auto Regressive (AR only) model is one where Yt depends only on its own lags. That is, Yt is a function of the 'lags of Yt'.

$$Y_t = \alpha + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + .. + \beta_p Y_{t-p} + \epsilon_1 \quad (1)$$

where, Y t − 1 is the lag1 of the series, β1 is the coefficient of lag1 that the model estimates and α is the intercept term, also estimated by the model. Likewise, a pure Moving Average (MA only) model is one where Yt depends only on the lagged forecast errors.

$$Y_t = \alpha + \epsilon_t + \phi_1 \epsilon_{t-1} + \phi_2 \epsilon_{t-2} + .. + \phi_q \epsilon_{t-q} \quad (2)$$

where the error terms are the errors of the autoregressive models of the respective lags. An ARIMA model is one where the time series was differenced at least once to make it stationary and you combine the AR and the MA terms. So the equation becomes:

$$Y_t = \alpha + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + .. + \beta_p Y_{t-p} \epsilon_t + \phi_1 \epsilon_{t-1} + \phi_2 \epsilon_{t-2} + .. + \phi_q \epsilon_{t-q} \quad (3)$$

Thus, ARIMA model is:
Predicted Yt = Constant + Linear combination Lags of Y (up to p lags) + Linear Combination of Lagged forecast errors (up to q lags)

ARIMA thus has P, Q, D where P refers to auto regressive lags, Q is the moving average and D is the order of differentiation. Thus, integration by just one order then the value of D Fig. 2. Arima Model would by 1, if by two then D=2 and so on. To predict values P, use PACF graph that is Partial auto-correlation function, for Q plot ACF graph and D is defined by the order of differentiation to make the data stationarity.

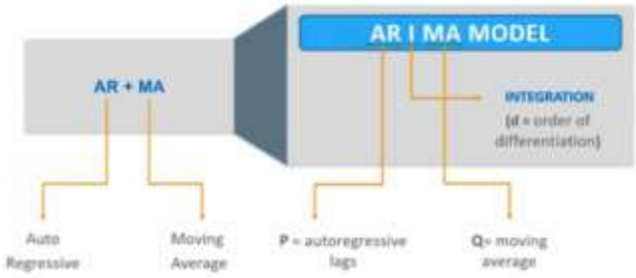

Fig -2: Arima Model

3. LOAD BALANCING

Load balancing, load matching, or daily peak demand reserve refers to the use of various techniques by electrical power stations to store excess electrical power during low demand periods for release as demand rises. Load balancing in distribution system is defined as maintaining the load currents approximately same on the three phases of the power system distribution network throughout the running time [4]. For load balancing we need to shift the loads from heavily loaded feeders to the lightly loaded feeders by satisfying some objectives such as minimum power loss maintenance in the system. Load balancing also improves the reliability and stability of the distribution system. The power loss in distribution system, mathematically, can be expressed as follows:

$$\sum_{i=1}^{n} r_i \frac{P_i^2 + Q_i^2}{|V_i^2|} \quad (4)$$

where Pi is active power, Qi is reactive power and ri is resistance of branch i, and n is the total number of branches in the system. The power losses depend on the real and the reactive power flows, which are related to the real and reactive loads connected. Using optimal load balance, phase voltages and phase currents are almost same in each phase subjected to satisfying thermal limits.

The proposed algorithm is used to redirect electric charges between different charging stations. The definitions of this algorithm include the variables to represent each charging stations from S1, S2, S3 up to Sn. Si is used as an iterative variable, a flag is set using the variable 'flag=0', In the initial step the algorithm compares the requirement of each charging stations. At a particular charging station if the requirement is greater than the predicted demand, the variable amt which stores the amount of charge is equal to required charge minus the predicted amount. For finding the next best charging station Snode is set as next best node taking the value if Si', Si' stores the address of the next best node. If all the operations are successfully performed the flag is set as 1. For output detection check if the flag is 0 then there will be no node available in the grid from which current can be withdrawn else the flag is set as 1 and the operation is considered as success.

Algorithm For Load Balancing

```
Compare the requirement of each station {S0,S1....Sn}
for each Si
        flag=0
        if (requirement>predicted)
                amt=required-predicted
        for next best Si'
                Snode=next best Si'
                If available in Si'
                        Si'_val-=amt
                        Si_val+=amt
                        flag=1
        If flag==0
                //unavailable
        else
                //success
```

4. ARCHITECTURE

The key aim involves providing an integrated environment for the sustainable and efficient Electric Vehicle charging station management by effective analysis of the data from the corresponding power supplies and users. It predicts the demand in a charging station and provides the required power. If more than enough energy is being produced or consumed, they are to be redistributed to balance the load. The entities involved Station Masters and E-Vehicle owners. The Station Masters are to be provided with functionalities i) to collect data from charging stations and communicate between the Power Suppliers and Customers ii) a new level of monitoring, protection, and control deeper into the distribution grid iii) cope with renewable using voltage regulation as well as distribution grid automation. The Vehicle Owners are to be provided with functionalities i) to easily connect the charging station nearby ii) in-can't customers with supply-side signals to change demand or feed-in a generation.

The system considers an ideal scenario where all vehicles run on electric power. Multiple charging stations are pre-installed over different locations.

- Demand Prediction: With the help of Google Maps API, the traffic over an area is extracted to get a possible power requirement in a particular area. Assuming, more traffic - more will be the consumption rate. A data set of previous power consumption of each charging station is maintained. Using a newly proposed Prediction Algorithm it is able to predict a day's power requirements in each charging station. Update the power requirement of the current day, in particular, charging stations by comparing the values from the data set prediction algorithm and traffic modules.
- Dynamic cost: By taking the average daily consumption

from the whole system, see how much it varies for each station and thereby updating the cost dynamically in accordance with the consumption rate.

- Load Balancing and fault detection: The whole system is networked over a smart grid with each power plant and charging stations as nodes. This, in turn, holds a key module in load distribution. Thereby a faulty node proves to be a faulty station. Weighted least connection scheduling to redistribute uneven power across stations.
- Database management: The entry and exit of vehicles, their specifications and possible waiting time are maintained in the database with the help of RFID and real-time database systems.
- Client-side : Nearest station by integrating and taking consideration of the price, waiting time and the distance to different stations.

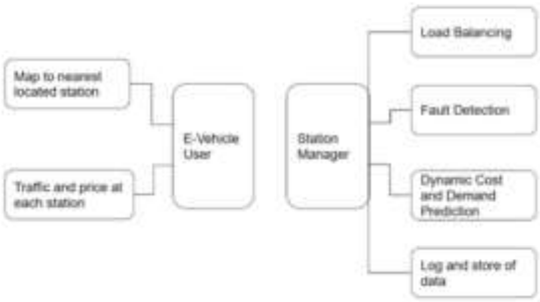

Fig -3: Block Model

Fig 4 shows the proposed control flow of the system. The input and the predicted data are validated. From the real time measurement, a requirement analysis is formulated from where the current required data is updated.

With this requirement analysis, the energy demand at the time of reading is found. if it's less than the amount from the predicted set, the cycle goes back for next time period's requirement analysis. But if predicted is less than that is required, the next best station is to be found for load transfer. The current station's dirty bit is reset as a measure for limiting the load intake from this station in accordance with other station's requirement analysis. This is turn reduces the state of deadlock in the system.

With the availability if stations, the value in both the stations are updated and the dirty bit is set. Requirement analysis is at a state of running for the next upcoming time periods until the system is shut down.

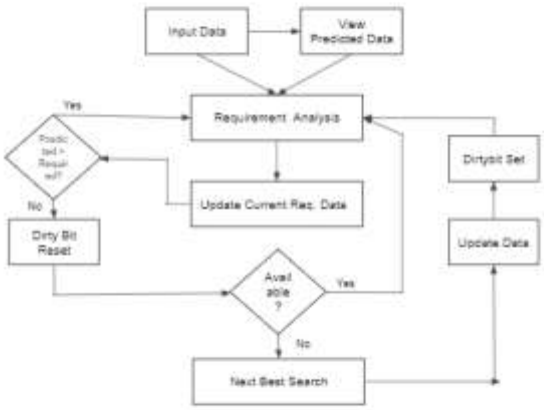

Fig -4: Control Flow

The selection of the next best station depends on a number of factors like the price, the waiting time, the distance to different stations etc. If a station is having high value for the predicted data but the reading in the input data founds to be a null or zero value, then that station could be labeled as a faulty node or station.

5. SIMULATION AND RESULT

The simulation of this experiment consists of developing 3 modules, which are 1. Prediction, 2. Load Balancing, 3. Fault detection along with a user interface. The prediction module predicts the power data based on demand as in fig 5. Fig 5(a) consists of power data of previous values in the grid. Based on this value and using time series analysis algorithm the value for the next day is predicted. Fig 5(b) shows the predicted data set. Figure 5(c) shows the predicted data values of another trained dataset alongside its demand prices predicted dynamically based on the predicted values

Figure 6(b) shows the confidence level of the predicted data set. It is used for fault detection inside the predicted data set. The next module is the load balancing system that balances the load between the working nodes (charging stations). Based on the developed load balancing algorithm current will be redirected to working nodes depending on the varying change in demand of each charging stations as shown in fig 6(a).

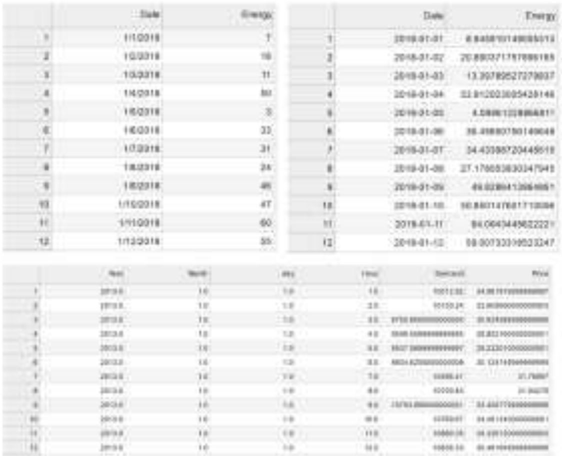

Fig -5: a) Dataset b) Predicted Set c) Demand and Price Formulation

Charding_Station	Demand	Change	%
id_0	452.02	-11.36	-2.51%
id_1	472.55	7.22	1.53%
id_2	495.23	14.25	2.88%
id_3	872.34	-10.80	-1.24%
id_4	80.18	-1.00	-1.23%
id_5	728.44	2.19	0.30%
id_6	674.25	13.47	2.00%
id_7	587.75	-25.24	-4.29%
id_8	618.35	-15.58	-2.52%
id_9	336.03	21.60	6.43%
id_10	92.22	-8.16	-8.85%
id_11	486.18	8.30	1.71%
id_12	480.23	-10.03	-2.09%
id_13	18.8	1.81	9.62%
id_14	285.24	7.72	2.71%
id_15	679.73	9.58	1.41%

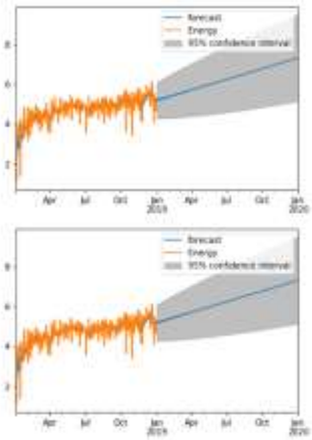

Fig -6: a) Demand Variance b) Confidence Interval

6. CONCLUSION

The proposed algorithm predicts the demand power figures of each charging station per hour using Time Series Analysis and balances the load between each charging station in real time. Redistribution to balance the load is maintained. When a charging station holds an excess amount of power or the demand for the day is below the predicted values, the proposed algorithm resolves this by handling the power distribution process in real time. Thus, the proposed system overcomes the issues of balancing load, predicts the demand prior to the running of the grid and effectively finds the faulted nodes.

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