ISA-PM-IPA-2021-01-09-ISO2PT-GRP-Electricity Demand Response Alert System

Electricity Demand Response Alert System (EDRAS)

NUS-ISS Master of Technology (Intelligent Systems)

Project Report

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1. Executive Summary

EMA has introduced a Demand Response (DR) programme to enhance competition in the wholesale electricity market. DR enables contestable consumers to reduce their electricity demand voluntarily, in exchange for a share in the system-wide benefits, in terms of reduction in wholesale energy prices as a result of their actions.

Such reductions in electricity consumption typically take place when wholesale electricity prices are high or when generation supply is tight. As such, incorporating DR in the wholesale electricity market could help to improve overall system efficiency, leading to cost savings for contestable consumers.

Benefits of the Demand Response Programme

The DR programme in the National Electricity Market of Singapore (NEMS) brings about several benefits. These include:

- Providing an additional option for consumers to participate in the NEMS through demand side bidding and to manage their electricity usage in response to price signals.
- Reducing the wholesale electricity prices during peak periods as more expensive generation units need not be scheduled to run.
- Promoting more efficient investments in the NEMS as DR is expected to reduce ‘peaks’ in electricity consumption. In the long term, this reduces the need to invest in expensive generation units that are only run infrequently to meet ‘peak’ demand.
- Providing an additional resource to improve system reliability as consumers reduce consumption in response to high prices during periods when supply capacity is tight (e.g. due to unplanned outages or gas disruptions).

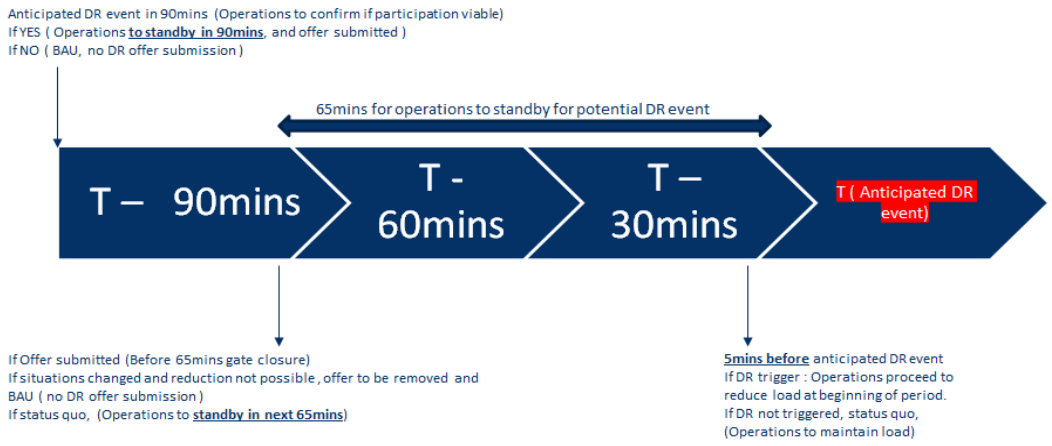
2. Business Problem Background and Objectives

In this section we will explain the business background

1. **Real-Time Notification of High USEP for Demand Response Participation**

   To participate in the programme, licensed load providers will have to submit demand bids into the NEMS for the periods in which they intend to offer load curtailments through a process called demand side bidding. The demand bids for a particular trading period will consist of the following: total load (in MW) for the registered block, a series of energy curtailment and price quantity tranches and the linear ramp rates (MW/min) as determined during the registration stage.

   Submission of the bids are required to be completed **within 65min** ("Gate Closure") of the trading, hence **active real-time notification** will allow the participant to have a **"look-ahead"** plan in order to bid into the system during the periods where the electricity prices are foreseen to be high.



2. **Uniform Singapore Energy Price (USEP) and Demand forecast**

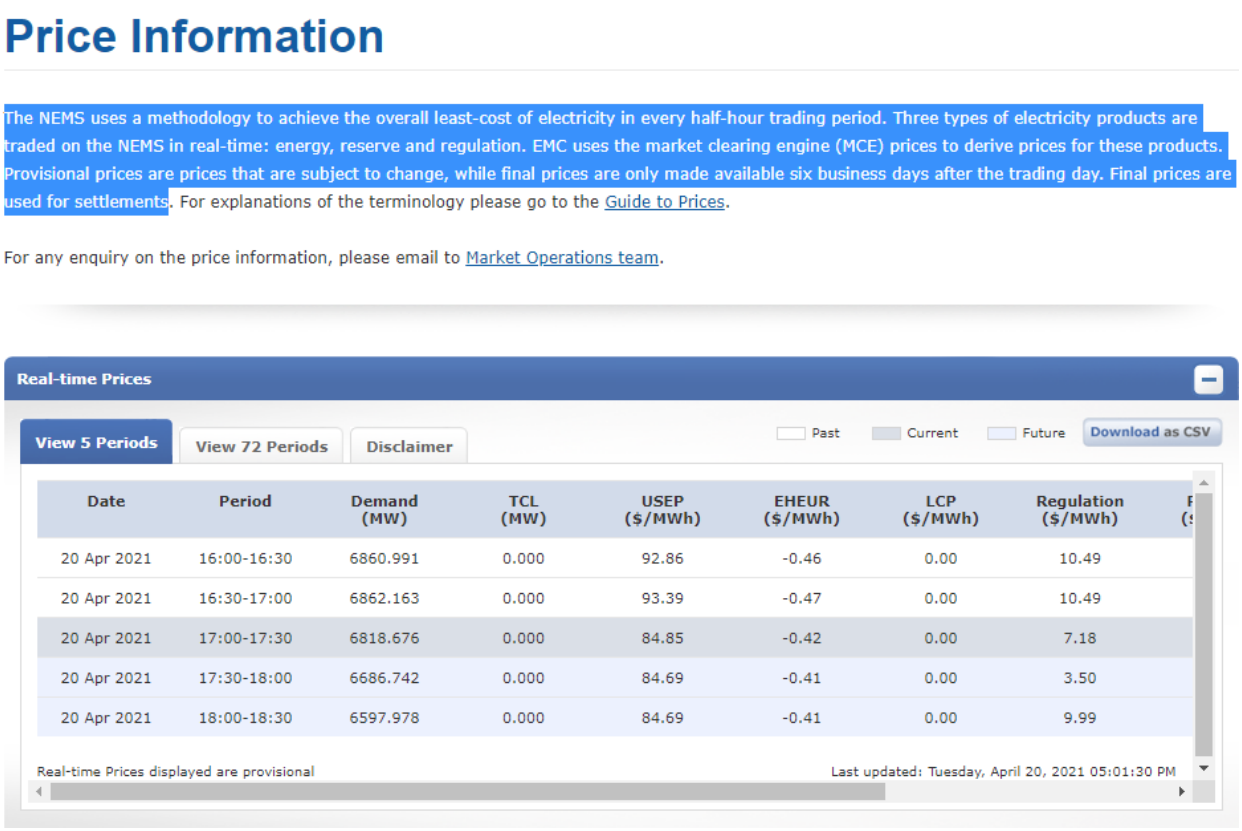
   A Demand Response is currently potentially activated if the USEP crosses above 1.5x Balance Vesting Price (*BVP). An accurate **forecasted USEP** will enable the market participant to bid in a time slot with a high chance of DR being triggered.

   *BVP = Currently set at S$125/MWh

3. Data Set

The data set is taken from the price information published in the Energy Market Company (EMC) website. The NEMS uses a methodology to achieve the overall least-cost of electricity in every half-hour trading period. Three types of electricity products are traded on the NEMS in real-time: energy, reserve and regulation. EMC uses the market clearing engine (MCE) prices to derive prices for these products.

There are 5 periods and 72 periods forecasted information.



Price Information

The NEMS uses a methodology to achieve the overall least-cost of electricity in every half-hour trading period. Three types of electricity products are traded on the NEMS in real-time: energy, reserve and regulation. EMC uses the market clearing engine (MCE) prices to derive prices for these products. Provisional prices are prices that are subject to change, while final prices are only made available six business days after the trading day. Final prices are used for settlements. For explanations of the terminology please go to the Guide to Prices.

For any enquiry on the price information, please email to Market Operations team.

Real-time Prices

View 5 Periods | View 72 Periods | Disclaimer

Past | Current | Future | Download as CSV

Date	Period	Demand (MW)	TCL (MW)	USEP ($/MWh)	EHEUR ($/MWh)	LCP ($/MWh)	Regulation ($/MWh)
20 Apr 2021	16:00-16:30	6860.991	0.000	92.86	-0.46	0.00	10.49
20 Apr 2021	16:30-17:00	6862.163	0.000	93.39	-0.47	0.00	10.49
20 Apr 2021	17:00-17:30	6818.676	0.000	84.85	-0.42	0.00	7.18
20 Apr 2021	17:30-18:00	6686.742	0.000	84.69	-0.41	0.00	3.50
20 Apr 2021	18:00-18:30	6597.978	0.000	84.69	-0.41	0.00	9.99

Real-time Prices displayed are provisional

Last updated: Tuesday, April 20, 2021 05:01:30 PM

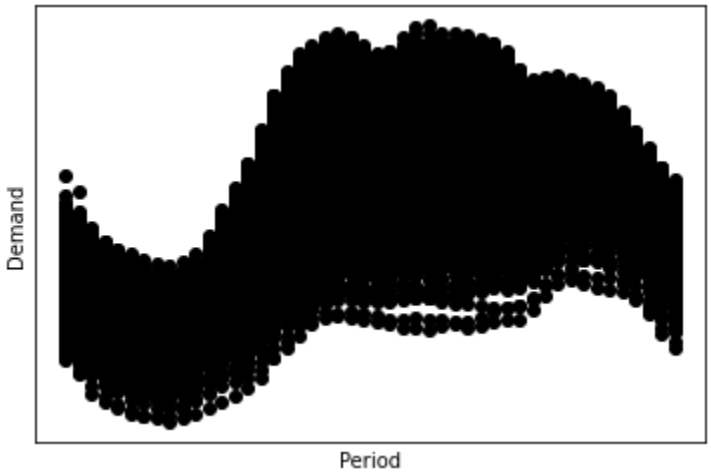
2 techniques used from retrieving/scraping data from the website in this project are

- TagUI
- Power Query within Power BI

4. Model Design

4.1 Correlation Observation & Analysis

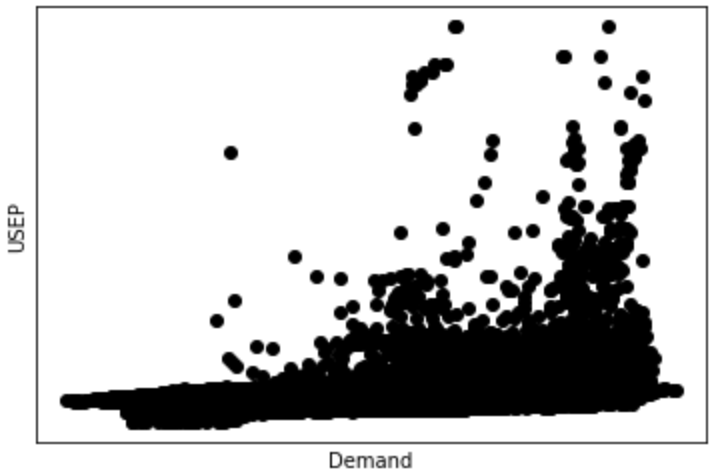
Based on the preliminary analysis on the historical data, the team has identified that the demand is highly correlated to the time of the day. As the period for each record is 30 minutes, which gives 48 total periods for one day.



Scatter plot for time Period vs Demand

As observed from the above scatter plot for the historical data between 1st Jan 2018 to 18 Mar 2021, it is very obvious that the trend of the demand for electricity is highly related to the time period of day. Starting from 0 am of the day, when most people would go to sleep and shut down their home appliances. After sunrise, people would resume their daily works and activities, it is expected the demand will surge. As the day comes to end, the demand would decrease.

Given that the demand is related to the time period, the team then explored the relation of the demand to the USEP since the Demand Response event could be triggered if the USEP goes above 1.5BVP.



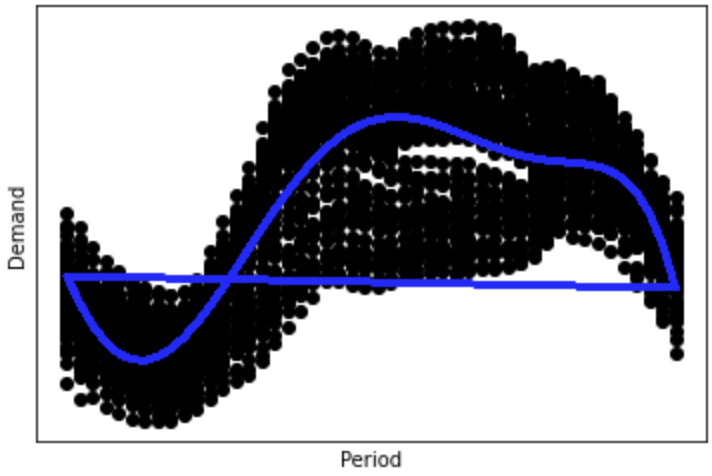
Based on the scatter plot for the Demand vs USEP, there is no clear pattern observed, but the USEP is likely to move up as the demand increases, and there is more likelihood of USEP surge when the demand is high.

4.2 Polynomial Linear Regression

Since one of the the objective of the project is to forecast the USEP and Demand so the user will have a better view of the price for the next few periods, and based on the analysis of the correlations, the team decided to develop two Polynomial Linear Regression models to predict the Demand based on the Period as well as the USEP based on Demand.

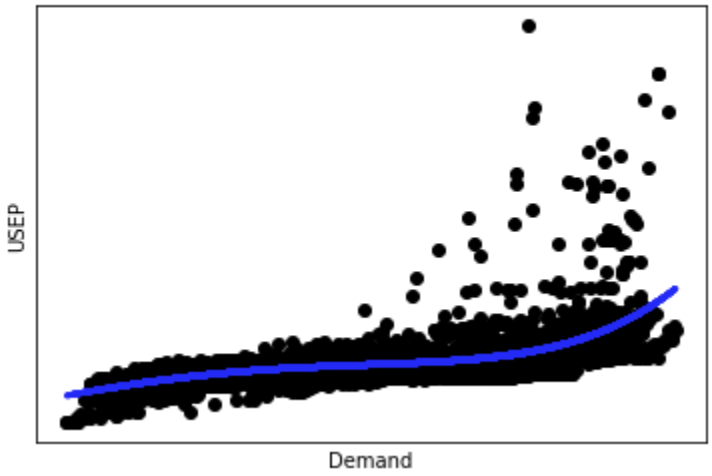
The team trained the model with historical date of 2018 - 2020 and validated the result on the 2021 data, below are the results:

```
Coefficient of determination: 0.71
```



Demand prediction with 0.71 r2 score

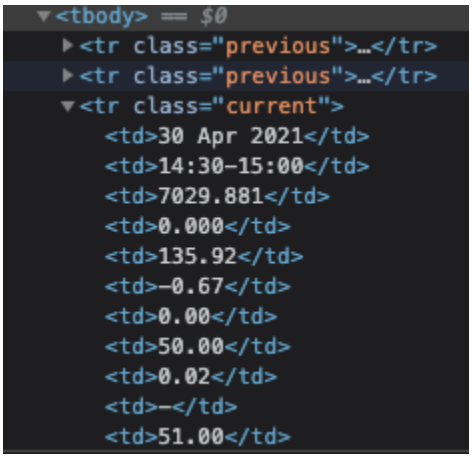
```
Coefficient of determination: 0.33
```



USEP Prediction with 0.33 r2 score

4.3 Data Extraction with TagUI

To make sure that the model is constantly improving, it is important to always feed the model with the latest data, otherwise the model will remain the same. By using the power of TagUI (now called RPA in Python package) which is taught in the course, the team is able to achieve web data scraping from the EMC website. The data is then transformed to Python Pandas dataframe and appended to the training dataset.

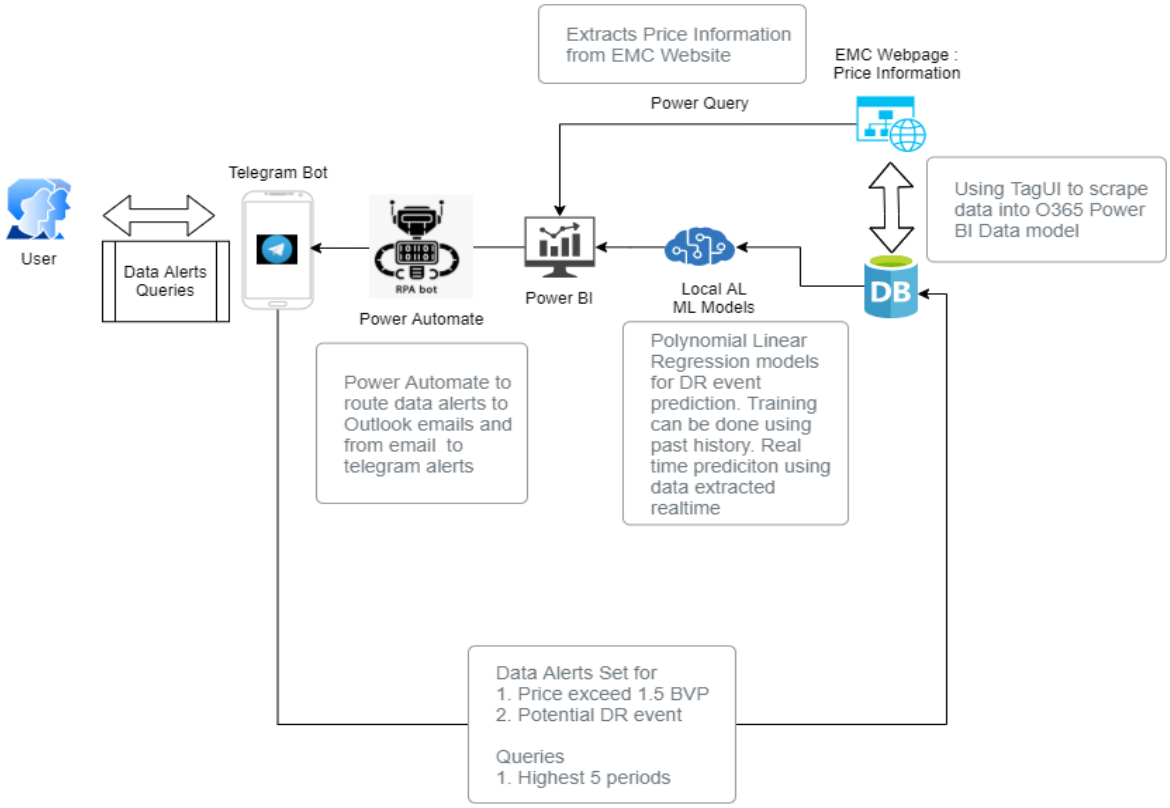


EMC website source data

```
r.init()
r.url('https://www.emcsg.com/marketdata/priceinformation')
r.wait(2)
print(r.read('//table[@class="ptable realtimePriceTable"]//tr[@class="current"]'))
data_list=r.read('//table[@class="ptable realtimePriceTable"]//tr[@class="current"]').splitlines()
data_list[0]=today.strftime('%d/%m/%Y')
data_list[1]=get_period_nbr()
data_list[2]=float(data_list[2])
data_list[3]=float(data_list[3])
data_list[4]=float(data_list[4])
data_list[6]=float(data_list[6])
```

Code snippet for TagUI

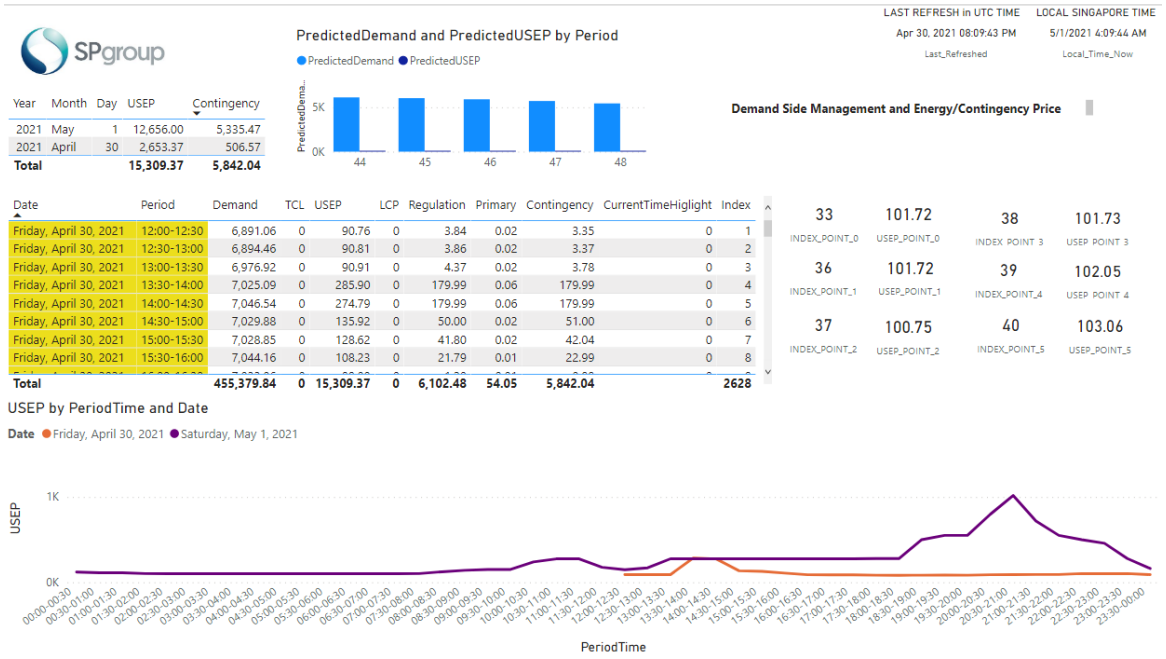
5. Design, System Architecture and Deployment



System Architecture

The system architecture is as shown above:

1. Source data from EMC is retrieved via
    - Power Query into Power BI for user information and configuration of data alerts for auto-notifications (via telegram bot)
    - TagUI to scrape real-time data into ML dataframe for price prediction.



Year	Month	Day	USEP	Contingency
2021	May	1	12,656.00	5,335.47
2021	April	30	2,653.37	506.57
Total			**15,309.37**	**5,842.04**

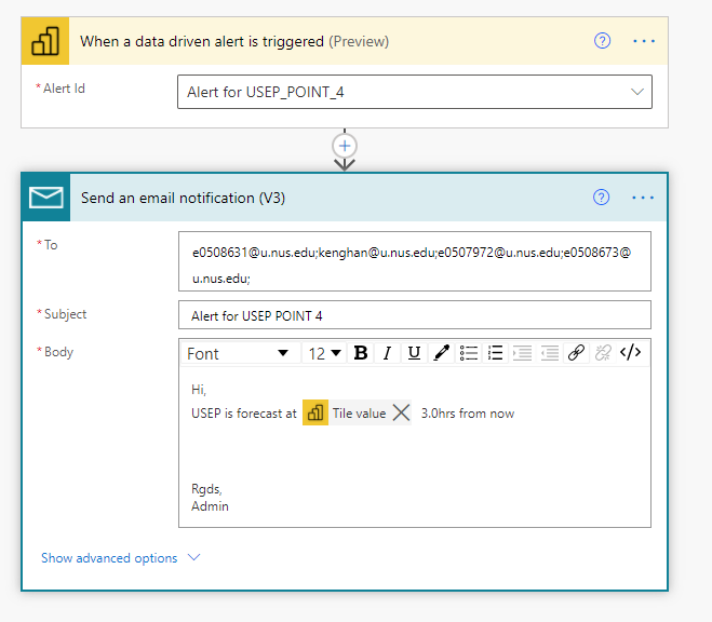
Date	Period	Demand	TCL	USEP	LCP	Regulation	Primary	Contingency	CurrentTimeHiglight	Index
Friday, April 30, 2021	12:00-12:30	6,891.06	0	90.76	0	3.84	0.02	3.35	0	1
Friday, April 30, 2021	12:30-13:00	6,894.46	0	90.81	0	3.86	0.02	3.37	0	2
Friday, April 30, 2021	13:00-13:30	6,976.92	0	90.91	0	4.37	0.02	3.78	0	3
Friday, April 30, 2021	13:30-14:00	7,025.09	0	285.90	0	179.99	0.06	179.99	0	4
Friday, April 30, 2021	14:00-14:30	7,046.54	0	274.79	0	179.99	0.06	179.99	0	5
Friday, April 30, 2021	14:30-15:00	7,029.88	0	135.92	0	50.00	0.02	51.00	0	6
Friday, April 30, 2021	15:00-15:30	7,028.85	0	128.62	0	41.80	0.02	42.04	0	7
Friday, April 30, 2021	15:30-16:00	7,044.16	0	108.23	0	21.79	0.01	22.99	0	8
Total		**455,379.84**	**0**	**15,309.37**	**0**	**6,102.48**	**54.05**	**5,842.04**		**2628**

33	101.72	38	101.73
INDEX_POINT_0	USEP_POINT_0	INDEX POINT 3	USEP POINT 3
36	101.72	39	102.05
INDEX_POINT_1	USEP_POINT_1	INDEX_POINT_4	USEP POINT 4
37	100.75	40	103.06
INDEX_POINT_2	USEP_POINT_2	INDEX_POINT_5	USEP_POINT_5

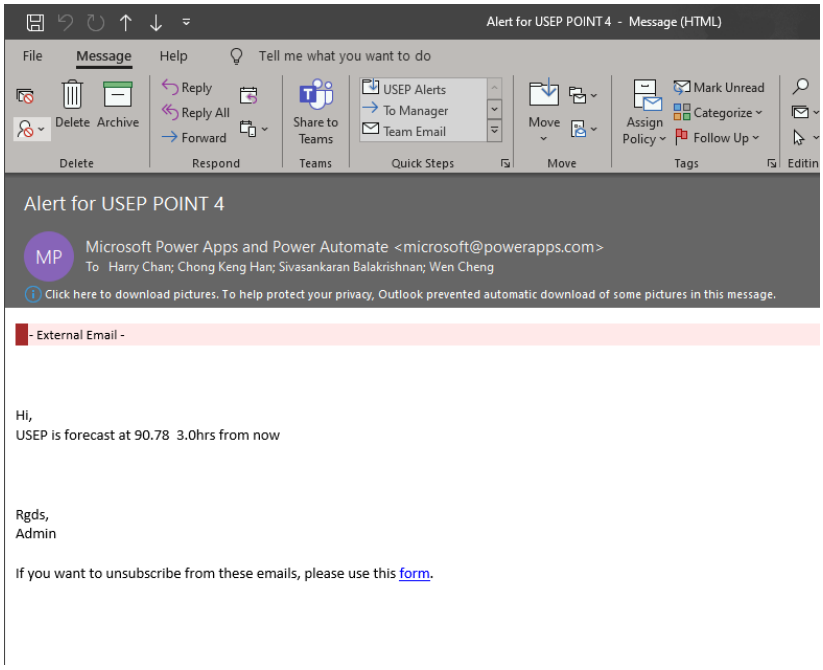
User Interface (Power BI Dashboard)

2. “Look-ahead” periods are configured as data points as alerts notification to the market participant in the demand response program. With this pre-notifications of potentially high USEP values, the market participant will be able to bid into the time periods which have a high chance of being triggered for load curtailment. This will translate to a monetary benefit of around $4500/MWhr for the periods of participation.

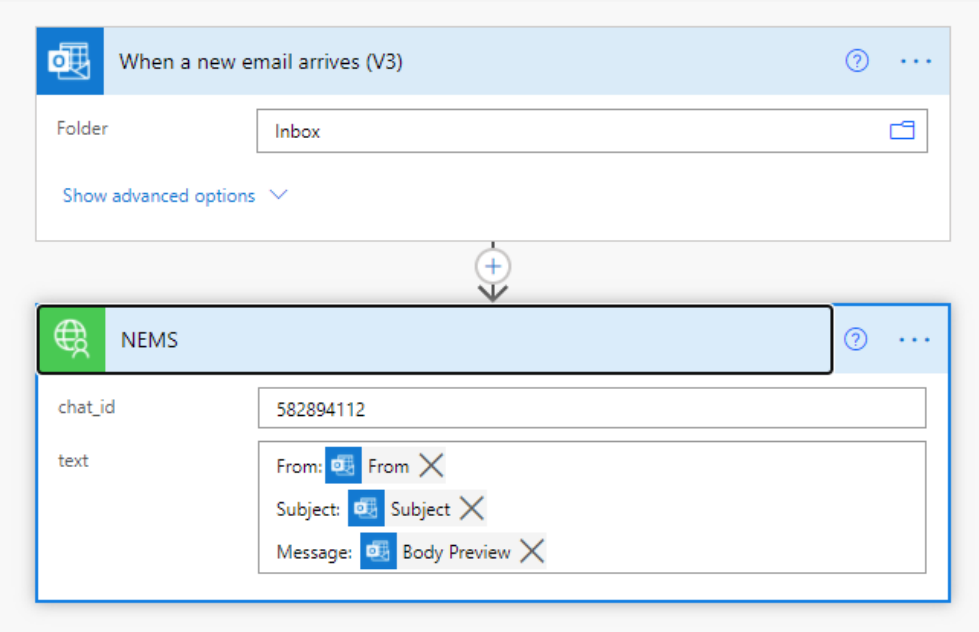
3. Using Power Automate / Flow (RPA) , the data alerts are configured with notifications to outlook and telegram Bot for proactive alerts. Both alerts (through email and telegram app) will make it easy, timely and so much convenient for the users to prepare for their action.

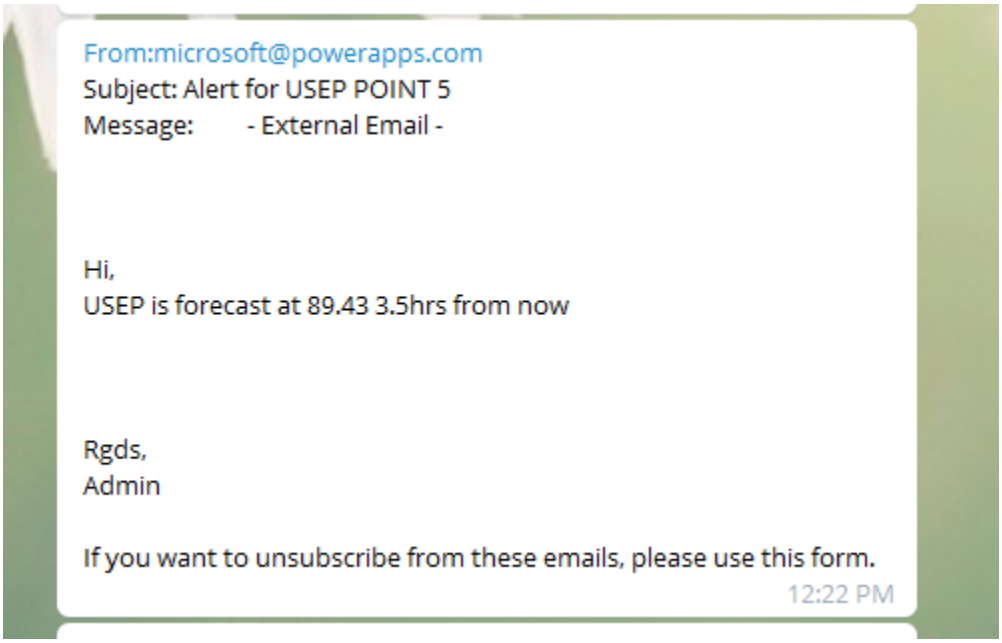


RPA (Power Automate) for email alerts based on forecasted high USEP



RPA (Power Automate) for email alerts for user notifications





RPA (Power Automate) for telegram bot alerts for user notifications

6. Overall Conclusion

With the increase of both electrical demand and renewable electrical resources, the demand response program will provide a major source of reliable and flexible capacity to ensure resource adequacy cost-effectively. The Forecast and notification system that the team implemented will enable potential Demand Response Market participants to have a pre-emptive notification and bid into the system during the forecasted periods that will have a high electrical USEP price. The eventual market benefit will enable the market participant to have a revenue of around $4500/MWhr. (Taking an example of a chiller plant which has a dispatchable load of 10MWhr, this will translate to a potential revenue of $45K per hour of participation when triggered.

7. References

[1] REVIEW OF THE DEMAND RESPONSE PROGRAMME IN THE NATIONAL ELECTRICITY MARKET OF SINGAPORE . EMA [Online]. Available: https://www.ema.gov.sg/ConsultationDetails.aspx?con_sid=20200922QYLPy2MaMxuu

[2] Demand Response Program . Just Electric [Online]. Available: http://justelectric.sg/wp-content/uploads/2021/01/Demand-Response-Program-Introduction.pdf

[3] DEVELOPING A FORWARD CAPACITY MARKET TO ENHANCE THE SINGAPORE WHOLESALE ELECTRICITY MARKET [Online]. Available: https://www.ema.gov.sg/cmsmedia/Second%20Consultation%20Paper%20-%20Developing%20a%20FCM%20to%20Enhance%20the%20SWEM.pdf

8. Appendix

Project proposal: Please refer to IRS-PM-PROPOSAL-2021-01-09-Stackable1-GRP-ElectricityDemandResponseAlertSystem(EDRAS).docx file

Mapped System Functionalities against knowledge, techniques and skills of modular courses:

- IPA: TagUI, Local AI -> for ML model to predict the USEP and Demand
- SRBP: Email automation -> for trigger of Email alerts
- RISM: Power Query, TagUI -> for automated data retrieval and processing