DEPARTMENT OF ELECTRICAL ENGINEERING
Final Year Project Proposal

1. Title of the Proposal

Applications of Neural Networks for Anomalous Consumer Energy Consumption Detection

2. Group Details

2.1. Student Details

Roll No	Name	Contact Number	Email
*EE-16177	Muhammad Waleed Hasan	+92 303 2844035	waleed.hasan.2502@gmail.com
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EE-16194	Syed Abdul Haseeb Qadri	+92 335 0349973	syedabdulhaseebqadri @gmail.com

* is showing the group leader

2.2. Internal Advisor

Name	Dr. Mirza Muhammad Ali Baig		
Designation	Assistant Professor		
Department	Electrical Engineering		
☑ Willing	☐ Not willing	Signature	

2.3. External Advisor

Name	Shahzeb Anwar		
Designation	Infrastructure Analyst		
Company	ENI Pakistan Limited		
PEC Number			
Contact			
Email			
☑ Willing	☐ Not willing	Signature	

2.4. <u>Funding/Sponsoring Organization (if any)</u>

Name	Ignite National Grassroots ICT Research Initiative (pending approval)

3. <u>Project Details</u>

3.1. <u>Project Type (Please mark ☑)</u>

☑	New
☐	Extension/Modification to previous project (if yes, specify title and year/batch)

3.2. <u>Nature of Project</u>

☑	Simulation-based	☐	Hardware-based

3.3. <u>Executive Summary/Abstract of the Project (Maximum 200 words)</u>

Electricity theft is a pressing, prevalent, and pervasive issue for both utility companies and their consumers, especially in densely populated developing countries like Pakistan. Conventional theft detection methods require manual inspection or intervention, and are not just expensive but also ineffective in identifying and isolating electricity thieves. The result is utilities incurring financial losses and consumers (even those who do not commit electricity theft) being deprived of electric power in areas where non-technical losses are exceedingly high.

The project described in this proposal aims to alleviate these problems through a data-driven approach to anomalous power consumption pattern detection, which can help utility companies identify potential electricity thieves. Concretely, the project's goal is to use Deep Learning to train different neural network architectures to detect anomalous power consumption patterns that are correlated with electricity theft. The neural network with the highest accuracy and lowest false positive rate will then be deployed on a cloud platform to act as a backend which utilities and distribution companies (DISCOs) can use to identify anomalous power consumption patterns in their own AMI data. In doing so, the model will empower utilities and DISCOs to carry out informed, data-driven identification of potential electricity thieves for further investigation.

3.4. Objectives and Deliverables

Objective 1   To complete *Deep Learning.ai*'s Deep Learning Specialization on Coursera [1] demonstrate a fundamental knowledge of Deep Learning tools and techniques. The relevant deliverable is a specialization completion certificate or specialization assignment solutions submitted to the internal advisor for evaluation.

Objective 2   To compare and contrast the relative performance of various neural network architectures in the context of electricity theft detection. Python-based Deep Learning libraries such as TensorFlow and/or Keras will be used to develop, train, and test these models and assess their selectivity (true positive rate) and specificity (false positive rate) along with any other relevant performance metrics [2].

Objective 3   To develop and deploy an accurate and efficient neural network model for electricity theft detection. The best model identified in through objective 3 will be deployed to a cloud-based service such as Google Cloud Platform (GCP) or Amazon Web Services (AWS) where it can be used by utilities as a black box to identify electricity theft in their own AMI data [3].

3.5. Beneficiaries

✓ Electricity Utility Companies: It is estimated that non-technical losses such as electricity theft constitute up to 40% of distribution expenditure of electric utilities every year [4]. For developing countries such as Pakistan with an endemic energy crisis and increase in demand outpacing generation capacity growth, minimizing these losses is crucial to the profitability of utility companies. Utilities can combine their AMI data with our cloud-based theft detection model to pinpoint instances of electricity theft amongst their customers at a fraction of the cost of existing, manual methods. This will result in lower operating costs for utilities, better energy efficiency, and improved cost per unit generation, thereby streamlining the power grid.

✓ Consumers: Operating costs associated with manual targeted anti-electricity theft operations are very high [citation needed]. As such, utility companies will rarely penalize individual consumers suspected of electricity theft. They will instead resort to load shedding/imposing power availability penalties on all consumers in areas affected by electricity theft [5]. This is an ineffective incentive structure: it does very little to

deter electricity theft long term while doing nothing to reward consumers that do not commit electricity theft. Our NN model will empower utilities to identify specific consumers suspected of electricity theft and target only them. This could eliminate unnecessary power availability penalties for the vast majority of consumers that do not contribute to NTL.

✓ AMI Manufacturers: Our NN will offer a cost-effective, software-based solution to targeted NTL reduction, with all the benefits this will entail. Consequently, it will act as an added incentive for DISCOs and utilities to invest in and popularize AMI as they will not have to invest in proprietary software to analyze readings from their devices. This will bring Pakistan closer to achieving its goal of turning its metropolises into smart cities

3.6. **Constraints and Potential Risks**

✓ Learning Curve: Theoretical and practical Deep Learning both have a steep learning curve, even for students with a solid foundation in computer science, algorithms, statistics, and graph theory. As electrical engineering undergraduates, all team members will have to learn elementary machine learning, Python programming, and develop algorithmic thinking.

✓ Generalizing to Pakistani Data: In order for the neural network to make accurate predictions, its must generalize well to electricity consumption patterns specific to Pakistani consumers. While the open source data sets published by the State Grid Corporation of China may be used in place of Pakistani data, differences in consumer behaviour between these two locales will limit the neural network's classification accuracy for Pakistani testing sets [6].

✓ False Positives: False positives for electricity theft detection may occur if a consumer's electricity consumption continues to be characteristically, low similar to that of electricity thieves. Minimizing false positive rates will require the neural network to distinguish between actual electricity thieves and consumers with uncharacteristically low power consumption due to legitimate causes such as being away on vacation.

3.7. Equipment/Components Required for Making Prototype/Working Model

S. No	Equipment Name	Details	Cost
1.	GCP Billing*	Using preemptible Google Compute Engine instance with 4 vCPUs, 12 GB RAM, 1 NVIDIA TESLA K80 GPU for 40 hours per week. Google Cloud Platform price calculator estimates monthly cost to be $43.80. Total cost for 7 months of testing and deployment. Conversion rate $1 = PKR 141.63 as of 12th May, 2019 [7].	PKR 37,219.05

* Applicable only if HPCC is unable to accommodate our project.

4. Project Management

4.1. Tasks

Preparation	Task 1	Complete Coursera's Machine Learning course and exercises.
	Task 2	Complete Coursera's Deep Learning specialization and exercises.
	Task 3	Clean/preprocess State Grid Corporation of China's energy consumption dataset for training, validation, and testing.
	Task 4	Complete preliminary literature review to identify architectures for testing and a suite of performance metrics to compare results.
Testing	Task 5	Develop and test all NN architectures identified in preparation stage using TensorFlow and AMI data from step 3.
	Task 6	Summarise performance of all models tested in step 5 to identify NN with best performance.
Deployment	Task 7	Deploy final neural network from Task 6 on cloud platform.
	Task 8	Develop a simple API that allows model to be used a black box for unseen data.
Report	Task 9	Prepare a report summarizing the design, development, and deployment of entire project, along with any relevant results.

4.2. Gantt Chart

Stage	Task Number	Task Description	2019					2020				
			Sep	Oct	Nov	Dec	Jan	Feb	March	April	May	June
Preparation	1	Coursera ML	■									
	2	Coursera DL	■									
	3	Data Preprocessing	■	■	■							
	4	Literature Review		■	■							
Testing	5	Model Testing			■	■	■	■				
	6	Model Selection						■				
Deployment	7	Model Deployment						■	■	■		
	8	API Development								■	■	
Report	9	Report Writing										■

5. List of Accessed Resources

[1] Ng, A. (2019). *Deep Learning | Coursera*. [online] Coursera. Available at: https://www.coursera.org/specializations/deep-learning [Accessed 10 May 2019].

[2] Chollet, F. (2018). *Deep Learning with Python*. 1st ed. Shelter Island, NY: Manning, pp.3-24. Dai, H. (2017). *henryRDlab/ElectricityTheftDetection*. [online] GitHub. Available at: https://github.com/henryRDlab/ElectricityTheftDetection [Accessed 20 Apr. 2019].

[3] Google Cloud. (2019). *Google Cloud Platform Pricing Calculator|Google Cloud Platform | Google Cloud*. [online] Available at: https://cloud.google.com/products/calculator/ [Accessed 12 May 2019].

[4] Glauner, P., Meira, J., Valtchev, P., State, R. and Bettinger, F. (2017). The Challenge of Non-Technical Loss Detection Using Artificial Intelligence: A Survey. *International Journal of Computational Intelligence Systems*, 10(1), p.760.

[5] Bhutta, Z. (2018). *Government likely to recover full cost of power theft from consumers | The Express Tribune*. [online] The Express Tribune. Available at: https://tribune.com.pk/story/1794534/2-government-likely-recover-full-cost-power-theft-consumers/ [Accessed 12 May 2019].

[5] Butt, N. (2018). *Nepra chief tells Senate panel: Cost of 5 percent power theft being paid by honest consumers | Business Recorder*. [online] Business Recorder. Available at: https://fp.brecorder.com/2018/10/20181017415990 [Accessed 12 May 2019].

 [7] Google Cloud. (2019). *Google Compute Engine Pricing | Compute Engine Documentation | Google Cloud*. [online] Available at: https://cloud.google.com/compute/pricing [Accessed 12 May 2019].

 [8] Ivanov, S. (2017). *Picking a GPU for Deep Learning*. [online] Medium. Available at: https://blog.slavv.com/picking-a-gpu-for-deep-learning-3d4795c273b9 [Accessed 12 May 2019].

 [6],[9] Zheng, Z., Yang, Y., Niu, X., Dai, H. and Zhou, Y. (2018). Wide and Deep Convolutional Neural Networks for Electricity-Theft Detection to Secure Smart Grids. *IEEE Transactions on Industrial Informatics*, [online] 14(4), pp.1606-1615. Available at: https://ieeexplore.ieee.org/document/8233155 [Accessed 20 Apr. 2019].

1. **Are all facilities to carry out this project available in NEDUET?**

   Yes. The NED High Performance Computing Center (HPCC) has the required facilities for students to carry out demanding computational tasks. As the project's primary goal is to train and test several Deep Learning architectures, the project will require a computing machine with a powerful graphics processing unit (GPU) and processor. The computers available in HPCC will thus allow us to train our models adequately.

   The internal advisor has also recommended using a high end computer in the NED Electrical Research lab for training the neural network model.

   If no, please mention how you will get the required facilities.

   If the HPCC is unable to accommodate our request for access to a powerful GPU/processor, a cloud-based solution for Deep Learning such as GCP, AWS, or Paper Space will be used [8]. Alternatively, the NED Electrical Research Lab computer can also be used for training.

2. **Does your project need industrial support (technical or software)?**
   No industrial support is required. AMI data from a local utility company, while beneficial, is not required.

   If yes, have you contacted the resourceful person? Please mention their details.

   Mr. Shariq Shaikh (shariq.shaikh@hotmail.com) and Mr. Iqbal Azeem (iqbal.azeem@neduet.edu.pk) from NED's electrical engineering department contacted K-Electric's Smart Meter Division with a request for an AMI data set on our behalf. Unfortunately, K-Electric declined our request for data.

3. **Does your project need site data? How will you access the data? Please mention the details.**

   As smart meter data from a local utility is not available, a public, open source data set published by the State Grid Corporation of China [9] will be used to train the model. The dataset contains energy consumption readings for 42,372 residential consumers over 1,035 days, with both regular and anomalous consumers flagged/labeled.

4. Are you aware of Program Learning Outcomes (PLOs)?

Yes. PLOs were discussed by NEDUET's FYP convener Dr. Umbrin Sultana during an FYP briefing attended by all group members. PLOs were also discussed by the group's academic advisor and internal supervisor, Dr. Mirza Muhammad Ali Baig, during an OBE presentation in 2018. Both presentations contained all the primary objectives that the group should expect to cover during the design and development of the project.

5. Are the following marked PLOs covered in this proposal?

☑	Yes	☐	No (revise proposal)

1	Engineering Knowledge	☐	7	Environment and Sustainability	☐
2	Problem Analysis	☑	8	Ethics	☑
3	Design/Development of Solutions	☑	9	Individual and Team work	☑
4	Investigation	☑	10	Communications	☑
5	Modern Tool Usage	☑	11	Project Management	☑
6	The Engineer and Society	☐	12	Lifelong Learning	☑

6. Have you discussed the PLOs listed above with your Internal and External supervisors?

PLOs have been discussed with both the internal and external supervisor. Both supervisors agree that the PLOs checked above are indeed covered by the scope of the project.

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Students

S #	Name	Signature
1	Muhammad Waleed Hasan	
2	Faiq Siddiqui	
3	Saad Mashkoor Siddiqui	
4	Syed Abdul Haseeb Qadri	

Internal Advisor

Name	Signature
Dr. Mirza Muhammad Ali Baig	

External Advisor

Name	Signature
Mr. Shahzeb Anwar	

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Signature of Project Committee Members Evaluating the Proposal:

S. No.	Name	Signature