A NOVEL ARCHITECTURE FOR ELECTRIC POWER LOAD FORECASTING IN A SMART GRID ENVIRONMENT

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by

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CERTIFICATE

This is to certify that the thesis entitled **“A Novel Architecture for Electric Power Load Forecasting in a Smart Grid Environment”**, submitted by **Mrs. M. Vetri Selvi**, to the Indian Institute of Technology, Delhi, is worthy of consideration for the award of the degree of **Doctor of Philosophy** and is a record of bonafide research work carried out by her. She has worked under my supervision and guidance and has fulfilled the requirements for the submission of this thesis. To the best of my knowledge, the results contained in this thesis have not been submitted elsewhere in part or full for the award of any degree or diploma.

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ABSTRACT

In a liberalized deregulated environment, Electric Power Load Forecasting (EPLF) is an important process in any power system network to make it an efficient, secure and consumer friendly electric power distribution utility. Electric power load increases tremendously especially for a Metropolitan city like Delhi due to climatic conditions, population growth, local area development, industries expansion, air pollution, thermal devices usage, etc. Hence, the accuracy of electric power load forecasting is a deciding factor for the electric power distribution utility to retain as an efficient and consumer friendly network. The proposed day-ahead EPLF models are built on a new multiple parallel inputs and output architecture with selected calendar, weather, smart grid factors and lagged electric load power features. This dissertation is mainly focused to deal with the selection and identification of best suitable features for creation of new architecture for EPLF model. The correlation analysis of EPL with respect to each selected feature is performed and presented. It also deliberates the implementation of RReliefF algorithm for selection and ranking of input features required for EPLF model. The real time data used for this research work were collected from Tata Power Delhi Distribution Limited (TPDDL). The EPLF models are developed using seven different techniques i.e: Multi-variate linear regression (MvLR) and Feed-forward neural network(FFNN), Cascade forward neural network(CFNN), Function fitting neural network(FFitNN), Layer Recurrent neural network(LRcNN), Standard LSTM deep learning network and Sequence-to-Sequence Regression LSTM deep learning network technique which are developed and implemented using MATLAB programming environment. The evaluation criteria for EPLF are presented with determination of various statistical errors. The performance of each model is analyzed and the results are presented with different techniques. As per the manner of usage of historical data, many methods have been proposed to study the performance of EPLF models. The performance of EPLF models are tested for different weather forecast errors. The proposed day-ahead ELPF models are evident for its simplicity, less measurement requirement and easiness in implementation with higher accuracy.

सार

एक उदारीकृत विनियंत्रित वातावरण में, इलेक्ट्रिक पावर लोड फोरकास्टिंग (ईपीएलएफ) किसी भी पावर सिस्टम नेटवर्क में इसे एक कुशल, सुरक्षित और उपभोक्ता अनुकूल बिजली वितरण उपयोगिता बनाने के लिए एक महत्वपूर्ण प्रक्रिया है। विशेष रूप से जलवायु परिस्थितियों, जनसंख्या वृद्धि, स्थानीय क्षेत्र के विकास, उद्योगों के विस्तार, वायु प्रदूषण, थर्मल उपकरणों के उपयोग आदि के कारण दिल्ली जैसे महानगरीय शहर के लिए बिजली का भार काफी बढ़ जाता है। इसलिए, बिजली के भार के पूर्वानुमान की सटीकता एक निर्णायक कारक है एक कुशल और उपभोक्ता अनुकूल नेटवर्क के रूप में बनाए रखने के लिए विद्युत बिजली वितरण उपयोगिता। प्रस्तावित ईपीएलएफ मॉडल नए मल्टीपल समानांतर इनपुट और आउटपुट आर्किटेक्चर पर चयनित कैलेंडर, मौसम, स्मार्ट ग्रिड कारकों और लैग्ड इलेक्ट्रिक लोड पावर सुविधाओं के साथ बनाए गए हैं। यह शोध प्रबंध मुख्य रूप से ईपीएलएफ मॉडल के लिए नई वास्तुकला के निर्माण के लिए सर्वोत्तम उपयुक्त विशेषताओं के चयन और पहचान पर केंद्रित है। प्रत्येक चयनित विशेषता के संबंध में ईपीएल का सहसंबंध विश्लेषण किया जाता है और प्रस्तुत किया जाता है। यह ईपीएलएफ मॉडल के लिए आवश्यक इनपुट सुविधाओं के चयन और रैंकिंग के लिए आररिलीफ एल्गोरिदम के कार्यान्वयन पर भी विचार-विमर्श करता है। इस शोध कार्य के लिए उपयोग किए गए रीयल टाइम डेटा टाटा पावर दिल्ली डिस्ट्रीब्यूशन लिमिटेड (टीपीडीडीएल) से एकत्र किए गए थे। ईपीएलएफ मॉडल सात अलग-अलग तकनीकों का उपयोग करके विकसित किए गए हैं जैसे: मल्टी-वेरिएट लीनियर रिग्रेशन (एमवीएलआर) और फीड-फॉरवर्ड न्यूरल नेटवर्क (एफएफएनएन), कैस्केड फॉरवर्ड न्यूरल नेटवर्क (सीएफएनएन), फंक्शन फिटिंग न्यूरल नेटवर्क (एफएफआईटीएनएन), लेयर रिकरंट न्यूरल नेटवर्क (LRcNN), स्टैंडर्ड LSTM डीप लर्निंग नेटवर्क और सीक्वेंस-टू-सीक्वेंस रिग्रेशन LSTM डीप लर्निंग नेटवर्क तकनीक जो MATLAB प्रोग्रामिंग वातावरण का उपयोग करके विकसित और कार्यान्वित की जाती हैं। ईपीएलएफ के लिए मूल्यांकन मानदंड विभिन्न सांख्यिकीय त्रुटियों के निर्धारण के साथ प्रस्तुत किए जाते हैं। प्रत्येक मॉडल के प्रदर्शन का विश्लेषण किया जाता है और परिणाम विभिन्न तकनीकों के साथ प्रस्तुत किए जाते हैं। ऐतिहासिक डेटा के उपयोग के तरीके के अनुसार, ईपीएलएफ मॉडल के प्रदर्शन का अध्ययन करने के लिए कई तरीके प्रस्तावित किए गए हैं। विभिन्न मौसम पूर्वानुमान त्रुटियों के लिए ईपीएलएफ मॉडल के प्रदर्शन का परीक्षण किया जाता है। प्रस्तावित दिन-आगे ईएलपीएफ मॉडल इसकी सादगी, कम माप की आवश्यकता और उच्च सटीकता के साथ कार्यान्वयन में आसानी के लिए स्पष्ट हैं।

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LIST OF ABBREVIATIONS

The symbols used in the thesis are listed below. Other symbols, not indicated in the list, have been defined locally.

EDU- Electric Power Distribution utility
EPLF- Electric Power Load Forecasting
DSM- Demand Side Management
CV1- Season
CV2- Month
CV3- Day of the Week
CV4- Week end factor
CV5- Holiday(Special day) factor
CV6-IndustryOFF factor
Ta - Air Temperature
Rh - Relative Humidity
Ws- Wind Speed
(D-1)P_L - Previous Day Electric Power Load
cnT -Type of Consumer
tfT -Type of Tariff
MvLR- Multi-variate Linear Regression
FFNN- Feed-forward Neural Network
CFNN- Cascade Forward Neural Network
FFitNN- Function Fitting Neural Network
LRcNN-Layer Recurrent Neural Network