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Artificial Neural Network Approach for Analysis and Prediction of Solar Radiation and Wind Speed in Telecommunication Systems

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Abstract: *The use of renewable energy sources in the power grid is essential for maintaining economic growth, especially for many African countries. Therefore, these countries can also install advanced artificial intelligence technology in their airport's power system to capture renewable energy. The paper aims to propose a real-time power management algorithm for a distributed hybrid renewable energy grid. It continues with the network modeling with the integration of solar and wind power. A multi-objective approach is proposed for the maximization of the spatial spectral efficiency and the energy efficiency as a function of the number of wind turbines and solar photovoltaic panels. Radio parameters for a Mobile Wireless inter-operability Medium Access (WiMAX) technology are considered for the simulation in MATLAB software. The results are quite mitigated but theoretically promising for the integration of green energy into the current telecommunication systems.*

Keywords: Artificial Neural Network (ANN); Green Energy; Solar Energy; Wind Energy; WiMAX Technology; Multi-Objective Problem; Power Generation Optimization; Theoretical Formulation

I. INTRODUCTION

The mobile cellular systems operate in a constrained spectrum and time slot [1], [2] with a rapid increase of customers, resulting in a high power consumption and also a source of CO2 emission. In [3], it was reported that the Information Communication and Technology (ICT) industries used about 3% of the global energy and produced around 2% of the CO2 emissions globally. Therefore, the ICT industries are experiencing a rise in related energy consumption of 16 - 20% per year. The power consumption distribution revealed that the power consumption for the core network (RAN) is roughly around 30%, the baseband processing unit about 10-15% and the cooling system about 15%. The number of base stations in 2015 was estimated to 6 million worldwide, which is expected to double in 2020 [4]. It is essential that the energy consumption of the current wireless system is reduced for the future ones [4], not only but also the global warming is a serious issue. In [5], it was emphasized a low electrification rate in the regions of Central Africa, estimated in the order of 13%, furthermore, the reference [6] indicated that the Sub-Saharan Africa has an electrification rate of 7% in its rural areas.

The developed countries, such as Finland, France and Germany, had set a road map for electricity with universal access for all at a 100% penetration rate by the year 2030 with the integration of renewable energy in the domestic consumption [7]. Many forums have emphasized the hybrid electric generation from renewable energies to increase the level of electricity for the universal access. Specifically, the International Energy Agency (IEA) [8], projected that the solar energy rate would account for about 11% of the total energy generated by the year-2050. Moreover, the global energy vision 2100, led by the German Advisory Council on Global Change, indicated that solar energy generation will contribute nearly 20% in 2050, and 60% in the 2100 with respect to the produced world energy [9]. Consequently, on the basis that all the mobile operators must use the green energy to supply the telecommunications on the continent, it will undoubtedly be a significant amount of green injected daily into many African nation electric grid. Referring to the statistics provided in 2015 by the Togolese Authority of Regulation of Telecommunication and Post services (ARTP), these reports showed a number of 858 GSM sites and 1080 BTS for 3 Generation [10]. Assuming, a 1000 GSM sites with an average power consumption of 4 kW per site that will approximate a demand of 40 00kW or 4 MW. In 2015, at Kumasi airport, the entire electrical system failed to work, including all the tarmac (runway) lighting system, when a commercial plane was about to land. The diesel generator also failed to start [11]. The blackout lasted about 5 to 6mn. Such a problem may cause voltage drop and the power quality, thus power stability management. The paper aims to propose a real-time energy control tool for a distributed hybrid renewable power grid while considering a telecommunication tool located in some key areas including an airport [12]. The contribution of this paper is in the proposition of power control on a distributed hybrid grid using an artificial neural network (ANN). The rest of the paper is organized as follows, section 2 formulates the mathematical derivation of the power efficiency as a function of the large number of wind turbines and the photovoltaic panels [13]. Section 3 explains the synoptic block diagram of the implemented control tool based on the artificial neural network and the simulation parameters. The next section makes a strong point of the presentation of the results and the analysis [14 – 15]. The final section (5) concludes the paper with a brief summary.

II. METHODOLOGY

A. System Modeling and block diagram

The system modeling has involved implementing the cascaded artificial neural networks as shown in Fig. 1. The artificial neural network is used to predict the global solar irradiation and the wind speed in advance. The data collection has involved collecting the daily irradiation and wind speed data from the NASA database. Some of these data were used for the training stage. The first artificial neural network captures the global solar irradiation for the optimal photovoltaic energy. The second artificial neural network predicts the wind speed for the optimal wind energy production. The third artificial neural network chooses the best among the available energy sources including the energy storage device on the distributed bus of the micro-grid. The system parameters for the simulation are given in the table 1. The path loss for a link between a macrocell and the user equipment and the user transmission power is modeled with a random noise. The number of solar panels and the number of wind turbines required for the mobile WiMAX system under consideration could be obtained by a regression algorithm in addition to the total power budget of the facility. This is not presented in this current work. With the knowledge of the average wind speed at Lome-site, which is around 4m / s. This implies that the selection of a small wind turbine will be suitable.

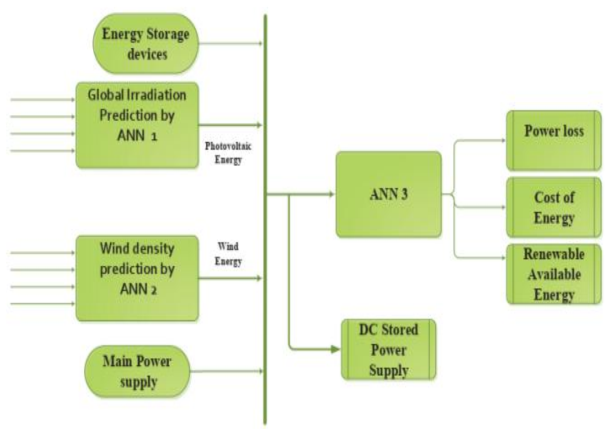

Fig 1: The cascaded ANN system

III. SIMULATION RESULTS AND ANALYSIS

This section shows the results and their analysis. The different ANN's predicted responses are displayed. The Fig. 2 shows the global solar irradiation for a chosen area. It should be noted that the optimal solar photovoltaic energy production will need precise data and a supervised system.

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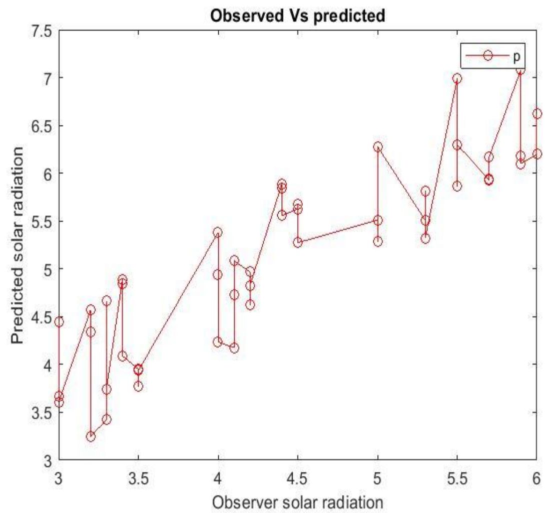

Fig 2: Predicted global solar irradiation using ANN1

This paragraph shows the output of the second neural network that captures the global solar irradiation in the range of 3.5 to 7kWh/m2/jr. The Fig. 3 suggests that for the wind speed below 2m/s, the ANN2-multiayer perceptron layer configuration may overestimate the prediction, while for wind speed above 6m/s the predicted value may be underestimated compared to the observed value on the site. For wind speed between 2m/s and 6m/s, the graph may indicate that a good match between the predicted data and the observed data is achieved

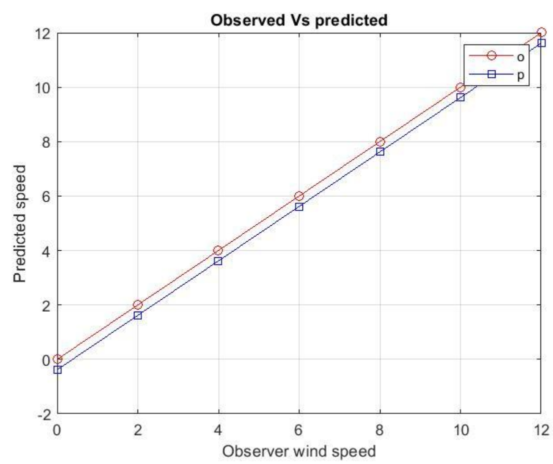

Fig3:Predicted wind speed using ANN2

The artificial neural network 3 gives information about the system energy efficiency and spectral efficiency of a fixed-mobile WiMAX station with the single input and single output (SISO) antenna configuration. It is supposed to serve a sensitive area, in this study an airport was considered. Three data services were considered, the system energy efficiency against the signal to noise ratio and the nodes respectively in the Fig. 4. The analysis (energy efficiency against the snr) shows that the energy efficiency is increased as the number of nodes increases. It reaches a peak point but a trade-off should be made, regardless of the type of data services. However, increasing the transmitting power of the macro-cell BS will not necessarily improve the area spectral efficiency, but when using more small cells deployment this could be done. Moreover, the small cells (femto, pico –cells) are very low power consumption devices, energy harvesting in the environment could be therefore very useful but their number under a given macrocell should be selected carefully.

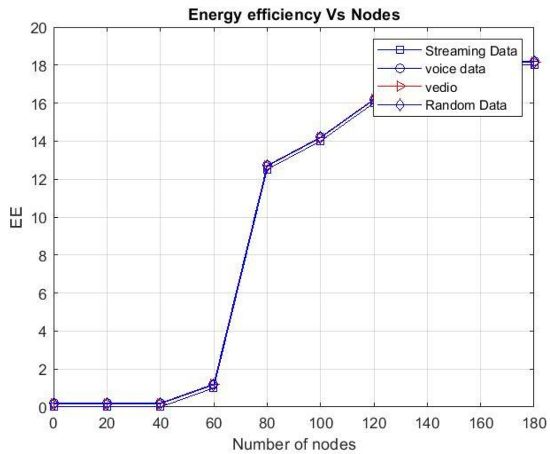

Fig4: Comparison between energy and nodes

Energy efficiency VS Nodes Old Data.

S No.	Number of nodes	Energy Efficiency Streaming data	Energy Efficiency Voice data	Energy Efficiency Video	Energy Efficiency Random data
1.	0	0	0	0	0
2.	20	0	0	0	0
3.	40	0	0	0	0
4.	60	1	1.2	1.3	1
5.	80	12.3	12.4	12.4	12.3
6.	100	13.5	13.3	13.4	13.5
7.	120	13.8	13.9	13.7	13.8
8.	140	14.5	14.4	14.3	14.6
9.	160	15.5	15.6	15.7	15.9

Energy efficiency VS Nodes New Data.

S No.	Number of nodes	Energy Efficiency Streaming data	Energy Efficiency Voice data	Energy Efficiency Video	Energy Efficiency Random data
1.	0	0	0	0	0
2.	20	0	0	0	0
3.	40	0	0	0	0
4.	60	1.7	1.8	1.6	1.7
5.	80	12.3	12.4	12.4	12.3
6.	100	14.1	14.2	14	14.2
7.	120	16.1	16.2	16.1	16
8.	140	17.2	17	17.1	17.2
9.	160	17.5	17.4	17.6	17.4
10.	180	18.1	18	18.2	18.1

IV. CONCLUSION

The integration of renewable energy into the power grid is very important today, especially for African countries that have a large reserve of natural energy resources. Predicted global solar irradiation is between 3.5 to 7 and predicted wind speed between 2m/s to 6m/s the observed wind speed is higher than the predicted wind speed, solar is a blessing for Africa, and most of the coastal countries can also equip the airport's electric system with advanced artificial intelligence technology. This paper explores and formulates the integration of green energy into the telecommunication system with power control based on an Artificial neural network. The contribution of this paper is in providing the power control of a distributed hybrid grid using an (ANN). The study shows the significance of the heterogeneous network and also suggests increasing the macro-cell BS transmitting will not improve the system spectral efficiency. The green metric is derived as a function of the injected green power and the availability of green energy. Many methods will be used to solve the multi-objective problem. The Pareto method can also be used as well as the dual Lagrange. Further validation of this problem can be done using on-site data and the dynamic monitoring of the number of solar panels and the wind turbines will ideally be necessary. Such data will be available if an advanced artificial intelligence system is installed in place. In future research, the algorithm of the power control will be considered based on the power system quality and stability in real-time monitoring. The system voltage drop and power loss will also be investigated.

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