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The Predictive Study on Soweto Wind Turbine Results and Port-Elizabeth

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***Abstract*—The results achieved for the research objectives of the Soweto Wind Turbine project were very encouraging. During comparison of prototype energy delivered versus time of day/month, results showed the energy production of Prototypes 1, 2 and 3 per month during operation at Soweto. It was observed that Prototype 3 outclassed Prototype 1 and 2 in terms of energy generated per month. Prototype 3 achieved 39.5 W output per wind speed of 1.17 m/s and was predicated to generate a maximum 40 kWh per month. Following information can be found in my recent published article, Implementation and Evaluation of a Low Speed and Self-Regulating Small Wind Turbine for Urban Areas in South Africa published at Engineering, Technology and Applied Science Research [ETASR] peer review open journal. This paper will present results on a predictive study which was subsequently done on implementing the same technology in the coastal regions of South Africa such as Gqeberha (formerly Port Elizabeth), where prevailing winds are much stronger. The results showed that, utilizing the empirically obtained data in Soweto, projected an energy output of up to 54.3 W per wind speed of 5.16 m/s (18.6 km/h) and up to 100 kWh per-month.**

Keywords*—*Coastal Regions, Predictive, Port Elizabeth

I. INTRODUCTION

In the past, South Africa's main energy option was to rely on electricity produced by fossil fuels such as oil and coal. Reliance on these energy sources continues to severely limit the national electricity. With an average of 2,500 hours of sunshine per year, and 4.5 to 6.6 kWh/ m^2 of radiation level, South Africa is among the top three in the world. The total wind power potential of South Africa is estimated to be 6,7000 GW, and is found to be competitive with the solar potential [1]. Wind as an energy source is only practical in areas that have strong and steady winds. South Africa's climatology allows for significant wind energy production especially along the coastal areas of the Eastern and Western Capes. The first large-scale wind farm in South Africa became operational in 2014 and based on the SAWEA report, there are 33 wind farms: 22 fully operational and 11 in constructions [2]. Amidst rising demands for decarbonization and sustainability in the 3rd world. Faced with wind energy proliferation, South Africa supports the growth in the renewable power sector since the risks posed by climate change to its resources from water security to agriculture, and shorelines are not isolated. The exposure of the economy to policies outside of its borders and the way it lowers demands for South Africa's coal given the spread of wind energy is unsurprising. From the spill overs of renewable, the impoverished Eastern Cape province, garnered 51% of South Africa's wind farms allotments. Consistent with the new policy, major banks have shown reluctance in securing financial backings for coal related ventures. Realizing, that the shift towards a low-carbon energy requirement involves capital spending in wind turbines built on precise high-tech tools on wind farms [3-8]. Moreover, generation of electricity with the usage of fossil fuels contributes in increasing of pollutions from CO2 and other greenhouse gases emissions which are harmful to negative impacts on the environment [9,10]. According to [11], utilizing renewable energy as an alternative energy source will help reduce environmental problems, essentially GHG emissions and air pollution. In this article, presentation will be done on results of the SEVEN rotor blade prototype (Design-3) wind turbine that was optimally designed and eventually implemented and tested in residential area in Soweto, Johannesburg, South Africa. A predictive study will be done using the Design 3 results to predict the possible implementation of the same technology in the high gust area of South Africa.

II. METHODOLOGY

The case study for the Eastern Cape province, South Africa [12] stated their research problems to be as follows. An assessment of generating electricity from wind for six sites of the Eastern Cape Province; Gqeberha (PE), Queenstown, Fort Beaufort, Makhanda/Grahamstown, Graaff Reinet and Bisho. The research was done at the Fort Hare University in South Africa from June 2014 to December 2014. The following technique and procedures were used in order to accomplish the project [12]. The series of five-year wind speed average data (01/2009 to 12/2013) for 6-Eastern Cape Weather Station were acquired at South African Weather Services (SAWS).

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The analyzing of data with MATLAB was done with the use of a Weibull distribution. The observation of variation of wind speed for six Eastern Cape sites from 2009 to 2013, the respective maxima fluctuated from site to site. Most inland sites trends had lower wind speed conditions, except Gqeberha and Bisho, which were located at very near the coast. Moreover, the minimum probability of an event in Gqeberha was 0.13 but the city also had the highest wind speed, while Fort Beaufort had the least spread among these sites/regions [12].

III. Result and discussion

It is of major importance that the assessment of wind potential is performed correctly. All characteristics must be considered as they will impact every aspect of the assessment, such as the evaluation of physical performance, investment viability and system design. Figure 1 illustrates the Unit-T anemometer tool that was used in Soweto to measure the effectiveness of wind periods for the area. According to [13], this tool is mostly used by meteorologists to analyze weather**.** The device has the ability to measure wind speed in (m/s) and (km/h) and temperature in (°C) and (°F***)***, with data logging capture. It also has the ability to give outputs in the form of waveforms for analysis**.** The device has Bluetooth functionality to transfer data to the user after measuring wind speed. The portable device can be plugged into the wind turbine and allowing convenient extraction of data.

Fig. 1. Unit-T 363-B Anemometer [13]

Table 1, 2 and 3 shows data that was collected for Soweto wind measurement effectiveness with the use of a Unit-T Bluetooth Anemometer every 24-hour intervals. The Anemometer was calibrated at one of the South African National Accreditation System (SANAS) laboratories. The highest wind power probability as in Figure 2 was found to be 2.3 m/s (8.28 km/h) and results were compared to that of Statistics of South African weather services.

TABLE I. Phase one of Soweto Wind Measurement Data

Date	Time	Temperature (°C)	Wind Speed (km/h)
28 07 2022	23:04:35	24.5	1.2
28 07 2022	23:04:05	24.5	0.0
28 07 2022	23:04:30	24.5	6.0
28 07 2022	23:04:55	24.6	5.8
28 07 2022	23:04:20	24.6	8.0
28 07 2022	23:04:45	24.3	4.2
28 07 2022	23:04:10	24.3	3.7
28 07 2022	23:04:35	24.5	6.3
28 07 2022	23:04:00	24.5	3.7
28 07 2022	23:04:55	24.6	5.8
28 07 2022	23:04:30	24.6	4.6
28 07 2022	23:04:05	24.6	7.9
28 07 2022	23:04:40	24.6	7.5
28 07 2022	23:05:15	24.5	3.7
28 07 2022	23:05:50	24.4	3.7
28 07 2022	23:05:54	24.4	5.0
28 07 2022	23:05:56	24.5	4.6
28 07 2022	23:05:35	24.6	0.0
28 07 2022	23:05:55	24.6	7.1
28 07 2022	23:05:20	24.6	0.0
28 07 2022	23:05:45	24.5	5.4
28 07 2022	23:06:10	24.5	1.4
28 07 2022	23:06:35	24.5	5.4
28 07 2022	23:06:00	24.5	1.4
28 07 2022	23:06:25	24.6	3.7
28 07 2022	23:06:50	24.6	0.0
28 07 2022	23:07:15	24.5	2.8
28 07 2022	23:07:02	24.5	1.4
28 07 2022	23:07:45	24.5	3.7
28 07 2022	23:07:20	24.5	0.0
28 07 2022	23:07:55	24.5	2.8
28 07 2022	23:07:30	24.5	4.2
28 07 2022	23:07:05	24.6	7.1
28 07 2022	23:07:40	24.5	0.0
28 07 2022	23:07:15	24.5	4.2
28 07 2022	23:07:50	24.5	4.6
28 07 2022	23:07:45	24.5	7.6
28 07 2022	23:07:10	24.5	5.4
28 07 2022	23:07:35	24.4	5.8
28 07 2022	23:07:00	24.4	6.3
28 07 2022	23:07:25	24.5	5.2
28 07 2022	23:07:50	24.5	6.3
28 07 2022	23:07:15	24.4	4.5
28 07 2022	23:07:40	24.5	3.4
28 07 2022	23:08:05	24.5	7.5

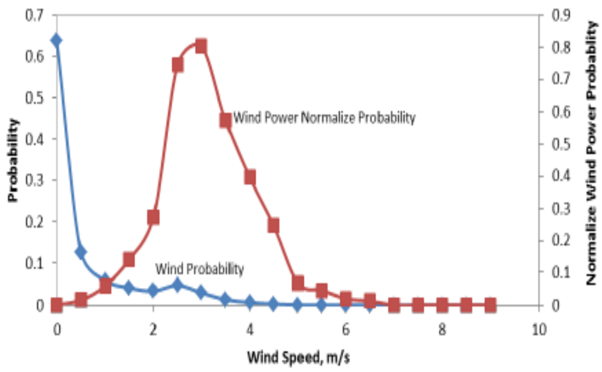

Fig. 2. Probability of wind and normalized wind power for Soweto area.

The average wind speed per year for Gqeberha (PE), as determined by Weather Spark [14], is 11.6 mph (approximately 5.16m/s). Knowing that Soweto has an average wind speed of 2.3 m/s, characteristic variables were found as shown in Table 4.

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TABLE II. PHASE TWO OF SOWETO WIND MEASUREMENT DATA

Date	Time	Temperature (°C)	Wind Speed (km/h)
12 04 2022	13:34:44	29.3	7.2
12 04 2022	13:34:14	29.4	8.8
12 04 2022	13:34:14	29.6	6.9
12 04 2022	13:34:39	29.6	9.6
12 04 2022	13:34:04	30.3	3.5
12 04 2022	13:34:29	29.2	4.3
12 04 2022	13:35:09	29.3	2.3
12 04 2022	13:35:34	29.7	8.3
12 04 2022	13:35:59	29.6	2.8
12 04 2022	13:35:24	30.1	0.0
12 04 2022	13:35:04	29.2	0.0
12 04 2022	13:35:29	29.1	3.7
12 04 2022	13:35:54	29.7	6.0
12 04 2022	13:35:19	29.7	5.3
12 04 2022	13:35:59	30.0	3.3
12 04 2022	13:35:24	29.3	0.0
12 04 2022	13:35:49	29.6	0.0
12 04 2022	13:35:14	29.6	6.7
12 04 2022	13:35:54	29.8	7.7
12 04 2022	13:35:19	29.2	3.1
12 04 2022	13:35:44	29.5	7.1
12 04 2022	13:36:09	29.6	7.7
12 04 2022	13:36:34	29.7	7.1
12 04 2022	13:36:54	30.4	6.7
12 04 2022	13:36:19	30.9	2.9
12 04 2022	13:37:44	31.4	8.8
12 04 2022	13:37:09	31.8	8.1
12 04 2022	13:37:49	30.8	0.0
12 04 2022	13:37:14	31.3	0.0
12 04 2022	13:37:39	31.7	3.7
12 04 2022	13:38:04	32.0	8.8
12 04 2022	13:38:44	30.6	0.0
12 04 2022	13:38:09	31.2	4.6
12 04 2022	13:39:34	31.7	1.4
12 04 2022	13:39:59	32.0	2.8
12 04 2022	13:39:39	30.5	3.7
12 04 2022	13:39:04	31.1	5.0
12 04 2022	13:39:29	29.3	4.2
12 04 2022	13:40:54	32.0	0.0
12 04 2022	13:40:59	31.0	6.7
12 04 2022	13:41:24	31.5	0.0
12 04 2022	13:41:34	33.5	7.1

As per my recent article published by ETASR peer review open journal (Engineering, Technology and Applied Science Research), Titled: Implementation and Evaluation of a Low Speed and Self-regulating Small Wind Turbine for Urban Areas in South Africa [15], results showed that Prototype 3 with maximum pitch angle of 12° produced the maximum output power of 39.5 W during testing and the maximum power output was achieved at average wind speed of 1.17 m/s (4.2 km/h) with energy production to generate a maximum 40 kWh per month

TABLE III. PHASE THREE OF SOWETO WIND MEASUREMENT DATA

Date	Time	Temperature(°C)	Wind Speed(km/h)
26 03 2022	17:56:55	26.9	7.1
26 03 2022	17:56:20	26.8	6.3
26 03 2022	17:56:45	26.6	3.7
26 03 2022	17:57:10	26.4	4.6
26 03 2022	17:57:35	26.3	6.3
26 03 2022	17:57:00	26.2	7.1
26 03 2022	17:57:25	26.5	5.4
26 03 2022	17:57:50	26.9	7.1
26 03 2022	17:57:50	26.8	7.5
26 03 2022	17:57:15	26.7	7.1
26 03 2022	17:57:40	26.6	6.7
26 03 2022	17:57:05	26.5	8.8
26 03 2022	17:57:30	26.4	4.6
26 03 2022	17:57:50	26.2	6.7
26 03 2022	17:57:25	26.9	6.7
26 03 2022	17:57:00	26.8	5.4
26 03 2022	17:57:35	26.7	0.0
26 03 2022	17:57:45	26.6	3.7
26 03 2022	17:57:20	26.5	6.7
26 03 2022	17:57:55	26.4	6.3
26 03 2022	17:57:30	26.2	6.7
26 03 2022	17:58:05	26.8	5.0
26 03 2022	17:58:40	26.7	5.8
26 03 2022	17:58:15	26.6	5.8
26 03 2022	17:58:10	26.5	6.7
26 03 2022	17:58:35	26.4	0.0
26 03 2022	17:58:00	26.3	7.9
26 03 2022	17:58:25	26.9	7.4
26 03 2022	17:58:50	26.7	7.9
26 03 2022	17:58:15	26.6	5.4
26 03 2022	17:58:40	26.5	6.9
26 03 2022	17:58:05	26.4	7.0
26 03 2022	17:58:30	26.0	8.3
26 03 2022	17:58:05	25.9	4.2
26 03 2022	17:58:30	25.7	6.7
26 03 2022	18:07:55	25.6	4.6
26 03 2022	18:08:20	26.1	2.8
26 03 2022	18:08:45	25.9	7.9

TABLE IV. PREDICTED WIND SPEED BETWEEN SOWETO AND GQEBERHA

Variables	Soweto	Gqeberha
$C(ms^{-1})$	4.2	6.3
$Vmp(ms^{-1})$	3.2	4.1
$Vop(ms^{-1})$	8.2	9.5
$Pd(Wms^{-2})$	99.5	207.8
$Vm(ms^{-1})$	3.6	5.6
K	1.1	1.8

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Figure 3, thus shows the predicted power output for Prototype 3 (Design 3) when it is applied in the Gqeberha (PE) region, assuming that it operates continuously. The analysis yields a maximum output power of 54.3 W at the average wind speed in Gqeberha.

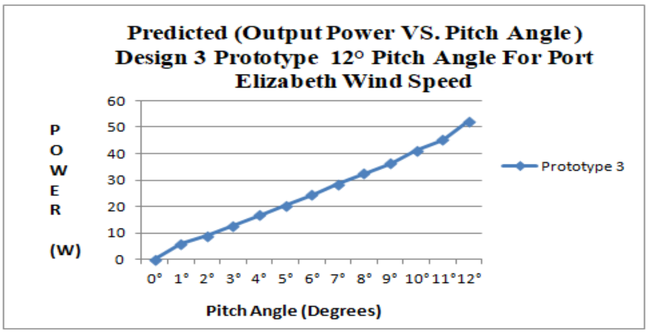

Fig. 3. Output power vs. blade maximum pitch angle as derived for Prototype 3 in Gqeberha region

Figure 4 shows kWh energy production per month over a year, when the Soweto Technology results were predicted for Gqeberha (PE)'s wind speed. It can be seen that the predicted production of energy per month in Figure 4 was positive when compared to energy production for the prototype 3 when it was implemented in Soweto.

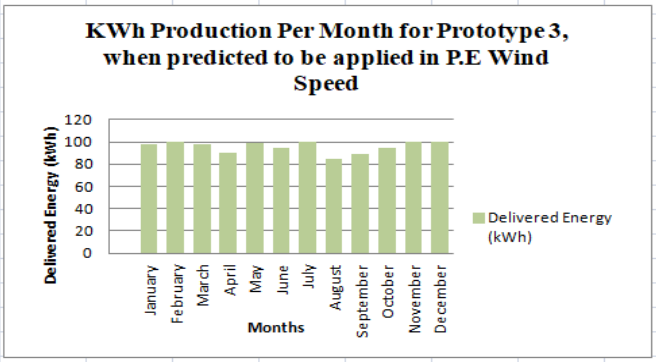

Fig. 4. Projected (kWh production vs. months) for Prototype 3 when predicted to be applied in the Gqeberha (PE) region

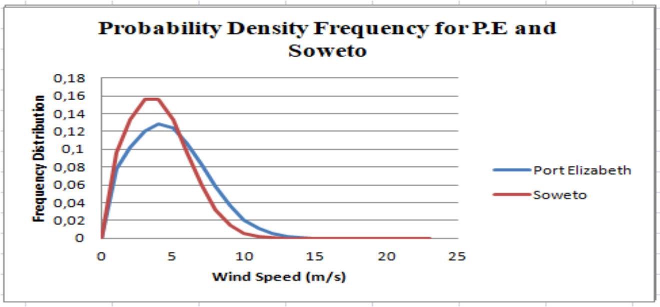

Fig. 5. The predicted annual probability density frequency for Soweto and Gqeberha (PE)

[12] In their published article 'Estimation of Wind Power Potential of Six Sites in Eastern Cape Province of South Africa', showed that while the minimum probability of an event in Gqeberha was 0.13, the city also has the highest wind speed. Then the predicted annual Probability Density Frequency for Gqeberha (PE) and Soweto in Figure 5 shows that Soweto has the maximum event probability of 0.16 with least wind speed.

The highest wind power probability derived from wind anemometer collected data in Soweto was approximately 2.3 m/s, demonstrating that the Anemometer was calibrated correctly as compared to average wind speed referenced in South African Weather Service (SAWS). The results showed that a predictive case study which was done for regions in Eastern Cape, specifically for the Gqeberha (PE) area, utilizing the empirically obtained data in Soweto, projected an energy output of up to 54.3 W per wind speed of 5.16 m/s (18.6 km/h) at Gqeberha and up to 100 kWh per month production energy. Therefore, the predictive case study between Soweto and P.E which was carried out contributed to new knowledge created within the field of study as it hasn't been done before and it is original.

IV. Conclusion

The benefits of this research were to achieve possible application of low-cost small-scale wind turbine in South Africa for low wind speed areas, thereby providing low-cost electricity to households and inhabitants in urban as well as in rural areas for a very large region in South Africa. This was achieved by developing a test prototype for low wind speed condition in Soweto, Johannesburg, South Africa, and Moreover prediction case study using Soweto test results were shared in number (2). Finally, a predictive case study for the Eastern Cape, focused on the Gqeberha (PE) area, was conducted using the empirically obtained data for the Soweto and Gqeberha (PE) areas, and it was concluded that it would be feasible to implement the Soweto technology in Port Elizabeth due to the results emanating presumably from the conditions at lower altitude (higher density air), and much higher wind speed resources at or near the coastal region.

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