International Journal of Research in Engineering, Science and Management
Volume 4, Issue 12, December 2021
https://www.ijresm.com | ISSN (Online): 2581-5792

A Review on Characteristics of Performance, Structure and Behavior of INVELOX Wind Turbine

Patel Vatsal Prashantbhai[1], Patel Pratham Narendrabhai[2], Patel Yashkumar Ganpatbhai[3*], Jakka Nikhil Balaji[4]
[1,2,3,4]*Student, Department of Mechanical Engineering, Leelaben Dashrathbhai Ramdas Patel Institute of Technology and Research, Gandhinagar, India*

***Abstract*: The presented Review paper consists of properties and data of the INVELOX wind turbine. It includes major drawbacks with the solutions regarding structural problems, vortex generation, reduction in velocity at outlet position by using theoretical data, analytical and practical data.**

***Keywords*: INVELOX, Venturi wind turbine, CAD, CFD, Speed ratio, Wind shield, Case study, Venturi effect, ACRIS, Field study, Clean and green energy.**

1. Introduction

INVELOX is a wind delivery system acceptable for wind power harnessing. One in all its innovative choices is its capability of incorporating multiple rotary engine generator systems at intervals of the Venturi section. INVELOX captures wind flow through omnidirectional intake or multi-unidirectional intakes and thereby there isn't any need for a passive or active yaw management system to orient the rotary engine. It accelerates the flow within the Venturi section that's later swollen and discharged into the duct setting through a diffuser.

[1] In this article, a right away arrangement with a windscreen has been projected to enhance the efficiency of INVELOX. The mechanic's characteristics and speed ratios of the initial INVELOX wind energy harvester was studied very well beneath completely different incoming wind directions. There was a heavy drawback with the initial INVELOX system, wherever the measuring system was positioned horizontally so that the outlet of the system might face the incoming wind, which might end in a big reduction within the mechanic's performance of the system. To enhance the performance of the INVELOX system, they tend to come back up with a replacement design plan, that is to get rid of the folding a part of the system and vertically organize the measuring system of the turbine beneath the funnel. The original INVELOX model is studied deeply and identified its problem in further study. One of the figures called 8 shows the problem that when INVELOX is placed horizontally as discussed above and once the angle between the wind direction and therefore the axis of the measuring system exceeds 120◦, the SR decreases dramatically and it faces problems like generation of vortexes and reduction in wind velocity at the outlet and or venturi section. Figure 2 shows all these problems with the Ansys simulation at the different inlets without letting directions. Figure 3 is that the speed vector diagram at the exit of the system beneath completely different wind directions. Figure 4 shows the total pressure contours in the symmetric plane of the original INVELOX system. The improved models are then analyzed and the generated data is compared with the original INVELOX models and it's come up with the solution of the original design by introducing model-1 which can be shown in figure 5. It shows the SR of the original design (model0) and improved vertical model (model1); from which it can be shown that the SR reduction is eliminated by a change in design. But there is still vortex generation at outlet position in model-1, which can affect the outlet as well as venturi section wind speed. So, another model is introduced called model 2 which has a windshield at the bottom portion of it. The surrounding wind which generates vortex in model 1 is hit with this cylindrical windshield and split into two portions; the upper portion goes inside the shield and due to impact with the windshield the wind loses its major velocity so it flows with the outlet wind which has more velocity compared with surrounding wind velocity. Due to this the vortex generation is eliminated and as well as SR is increased which can be shown in figure 5. From figure 5 it's identified that model 2 has the highest SR compared to all other models. From the above discussion, it can be summarized that after removing the bending section in the original INVELOX design and introducing a straight vertical section the SR is dramatically increased, and to gain more increment in SR the windshield is introduced at the outlet portion of venturi.

*Corresponding author: yashpatel0410.yp@gmail.com

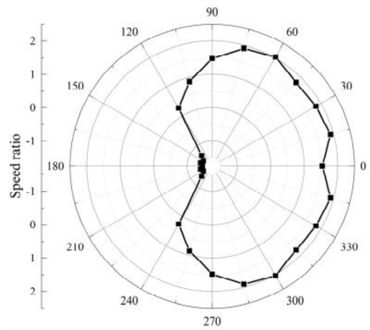


Fig. 1.

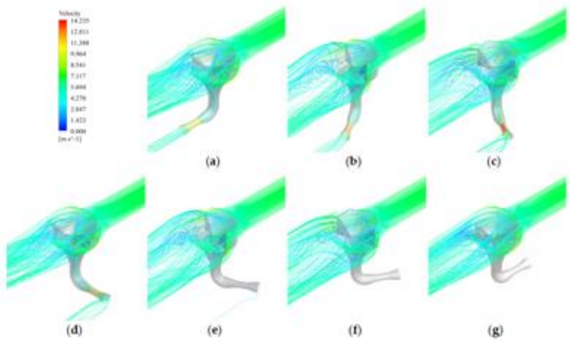


Fig. 2. Streamlines of the invelox under different incoming wind directions. (a) θ=0º (b) θ=30º (c) θ=60º (d) θ=90º (e) θ=120º (f) θ=150º (g) θ=180º

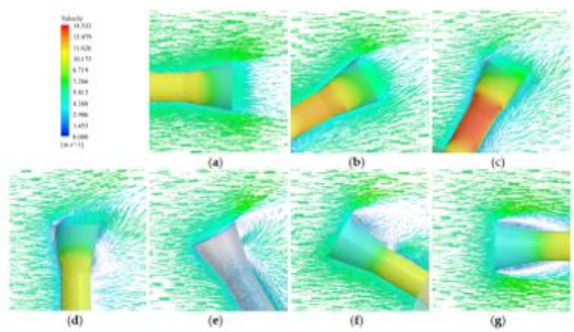


Fig. 3. Velocity vector at the exit of the original Invelox model under different incoming wind directions. (a) θ=0º (b) θ=30º (c) θ=60º (d) θ=90º (e) θ=120º (f) θ=150º (g) θ=180º

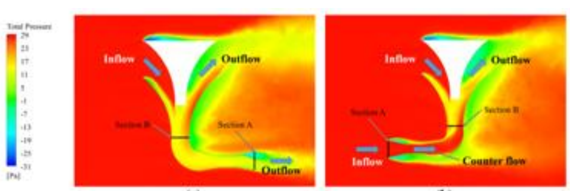


Fig. 4. The total pressure contours in the symmetric plane of original Invelox system, (a) θ=0º and (b) θ=180º

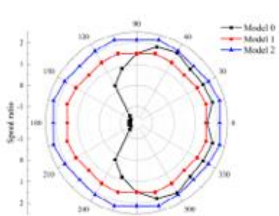


Fig. 5. The speed ratio of different configurations under different wind directions

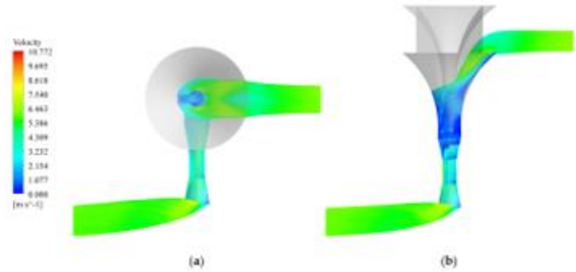


Fig. 6. The streamlines through the Venturi tube, (a) θ=90º in Model 0 and (b) θ=0º in Model 1

[2] INVELOX suffers from a significant structural downside. once the wind speed or density is high, the structure shows instability. If the wind speed reaches an important level, its force and momentum around the base could destroy the total structure. during this article, a unique modification has been done to the INVELOX structure. ACRIS could be a mechanism that improves each potency and structural behavior of the INVELOX system. ACRIS could be a modification to the roof of the INVELOX. ACRIS is intended for 2 things. once the system works at the high-speed wind, the INVELOX system won't be at risk of destruction thanks to the wind speed. Here, a fuzzy controller is employed to manage the orientation of the roof. Another input is that the wind orientation. this can be one of all the disadvantages of the INVELOX style. Singularity will occur within the INVELOX system thanks to hydraulics, like turbulence flow and eddy current flow downstream of the flow. The optimum flowing speed at the Venturi section of the generator is 25 m/s. one of the benefits of the ACRIS mechanism is to succeed in and maintain the optimum flowing speed within the Venturi section once the wind speed is within the low-level vary. once the outside wind speed is high, the most responsibility of the ACRIS mechanism is to keep up structural stability. To do so, the orientation of the roof changes in a very approach that decreases the wind force on the structure. Moreover, once the outside wind speed is high, the flowing speed at the Venturi section can cross the best speed and at some purpose, it may be even harmful to the generators. The ACRIS orientation for high-speed winds not solely decreases the wind force on the structure however additionally decreases the flowing speed within the Venturi section so that it may be close to the best speed. Figure 6 shows the singularities within the INVELOX system for various roof orientations. additionally, in Figure 7, the best curve for the roof orientation is delineated. within the best curve, the flowing speed is within the proximity of 25 m/s. The best curve is considered to be the favorable orientation of the roof and also the output of the system should match this curve. Here, the effectiveness of the ACRIS mechanism in raising the performance of INVELOX and its potency is investigated. to match the performance of the INVELOX with and while not the ACRIS mechanism, CFD simulations were performed. It shows that the ACRIS mechanism has increased the performance of the INVELOX system up to 18 in increasing the wind speed within the Venturi and preventing the wind from escaping from the alternative aspect of the incident wind. Figure 8 shows the performance of INVELOX and ACRIS at the wind speed of 2

m/s. because it may be seen, the flowing speed at the Venturi section for the ACRIS mechanism is 4.46 m/s, whereas the flowing speed for the INVELOX system is 3.8 m/s. Again, the ACRIS mechanism valid its capabilities. It indicated a 12% improvement in the performance of the system and prevented the wind from escaping. it had been noted before that the best flowing speed for the generators within the Venturi section is 25 m/s. Therefore, it's very important to analyze that system will reach the best flowing speed at the Venturi section earlier. This result shows that ACRIS will work AN best flowing speed in a very lower wind speed compared to the INVELOX system. once analyzing the Venturi wind speed within the simulation, it's necessary to see the energy output of the system. By viewing the annual Venturi wind speeds of the ACRIS and INVELOX turbines, an evident increase may be ascertained within the ACRIS output. An alternative energy chart from the Venturi may be obtained victimization AN equation and also the wind speed profile of the region is shown in Figure 9. This shows a good improvement for ACRIS versus INVELOX. A bigger space of pressure is applied to the INVELOX structure, whereas the ACRIS style with its omnidirectional angle adjustability will cut back this result on the structure.

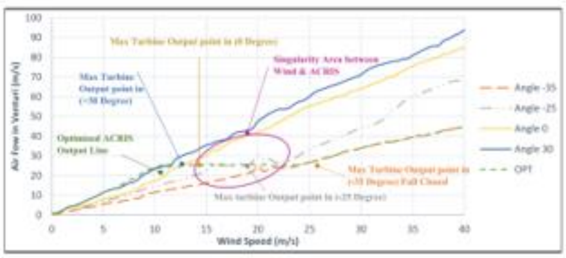


Fig. 7. Singularity and optimal curve

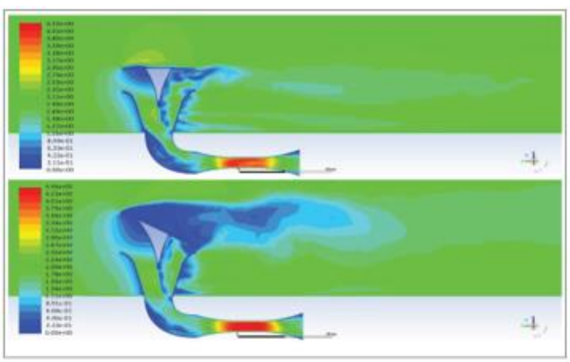


Fig. 8. Comparison of two mechanisms at wind speed of 2 m/s

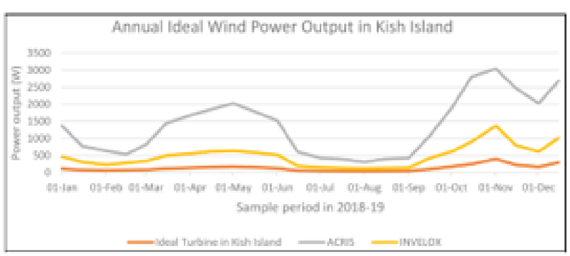


Fig. 9. Annual ideal output (W) comparison of Kish Island, according to Betz limit

[3] The main aim of this study is to propose some modifications to INVELOX to decrease the quantity of the escaping air. The new projected curtain system rotates with the incident wind and closes the trail of the escaping air. Some guiding surfaces are value-added to direct the flow toward the inner region of INVELOX, rather than escaping it. These guiding surfaces are placed within the lower funnel of INVELOX. The effects of the approaching wind direction and turbulent intensity on the INVELOX performance are investigated. 2 shows the pure mathematics of their projected INVELOX and also the corresponding dimensions are given in Table 1. 3 shows the air path lines getting into INVELOX and also the escaping air. 4 shows a schematic of the airflow pattern within INVELOX. INVELOX just accepts wind from all directions, a good portion of the captured wind escapes from the other open face. To decrease the escaping air, a curtain style is projected, as portrayed in Fig. The curtain keeps 1/4th of the intake space hospitable air flow, whereas it blocks the remaining 3/4th opposite space. It is connected to a little wing to align the curtain to the direction of the incident wind. This wing is simply a suggestion for orientating the curtain system to the approaching wind and it's not been thought about within the numerical simulations. the most feature of this style is that it keeps the omni-directionality of INVELOX. The curtain lets the air enter the INVELOX from that water and at an identical time, prevents the air to flee from the other face. [4] During this study, the performance of INVELOX turbine, beneath the impact of geometric changes within the nozzle-diffuser section, is investigated by Finite Volume technique. To follow an additional realistic approach, the wind speed equation is applied to the water. The results of the quantitative relation of the length to nozzle cross-sectional space, diffuser length, diffusion angle, varied nozzle style standards, conjointly the angle and height of the intercalary projection were delineated by the pressure and rate distribution contours. The results showed that once the quantitative relation of the nozzle length to throat diameter rises to associate optimum limit, the channel rate will increase, and at that time, it begins to decrease. Also, to use the perfect nozzle the system was geometrically optimized to fulfill the INVELOX system necessities. After that, the ability rises thanks to adding the outlet projection was studied, associated an acceptable geometric quantitative relation was achieved. Finally, the system performance, once the rotary engine was shapely as a uniformly loaded mechanism disc was investigated to seek out the foremost economical rotary engine. Wind energy is the second greatest supply of energy that be the fastest-growing renewable energy technology over the past four decades. Additionally, to the mechanics performance of turbines, since the output power of a rotary engine is proportional to the cubical wind speed, the wind flow plays an important role within the economization of this business. this implies even a little increment in wind speed causes a major increase within the power output. Hence, several researchers have tried to extend the wind speed within the rotary engine rotors. Inducted turbines, rotary engine rotors are encircled by a chamber to direct the flow into the system to extend the wind speed within the rotors, showing fascinating leads to the economic viability of the wind energy business investigated the impact of nozzles on wind lenses and showed that the water

form contributes to the power production. The scale and style of the INVELOX system is this technique given by Alaei and Andreopoulos is intended to board wind from all directions. Four fins are embedded within the chamber of the INVELOX tower, conductive to any improvement within the performance of the chamber once capturing the free stream flow, N is the Wind Shear Constant. Hence, the wind speed equation applied to the domain is up to the wind speed of the surroundings. In this study, the three-dimensional Reynolds-Averaged Navier-Stokes equations are the governing equations of the flow of incompressible Newtonian fluid with thermophysical properties. To model the mechanism disc accurately, the experimental information of the pressure drop for the varied free stream velocities were used. To initiate the method of applying geometrical changes, the nozzle section is analyzed parametrically. The procedure of applying changes will be determined in Fig. 5.fig. vi shows the impact of the nozzle length on the flow behavior within the nozzle-diffuser section of the INVELOX system; the rate and pressure constant graphs are given for various ratios of the nozzle length to throat diameter. To analyze the diffuser section in terms of 2 effective parameters, together with L* and g, the Response Surface technique was employed in style-specific computer code. g varies between 0.57 and 1.04 and L* ranges from 0.16 to 2.16, as shown in Fig. 8. The results indicate a certain growth within the quantitative relation of the flow speed within the nozzle-diffuser section to the rate of the free stream, that is achieved by the improvement method. enclosed that the length of the diffuser half contains a direct relationship with the rate at the throat, and once it will increase, higher efficiencies are often achieved. By excessive rise or decline of the length or gap angle of the diffuser, the channel flow separates, leading to a big call in the flow speed. Here, the result of adding a projection to the output of the system is studied. The effective parameter examined at this stage is the quantitative relation. Therefore, flanges with ratios of0.083, 0.125, 0.133, 0.15, 0.166, 0.208, 0.25, and 0.33 were studied. As delineated, by increasing this quantitative relation from 0 to 0.15, the native pressure drop will increase, and as a result, suction will increase. However, in geometries with ratios quite 0.15, the reduction of mass flow initiates. The summary of the pressure field and contour round the projection diaphragm once H=D ¼ (0.15). As shown, adding projection causes flow separation on its wall, which creates a non-aggressive zone within the outlet of the system. This lowering 0.17 comparison of Input and foreseen values of RSM model for throat speed. The ultimate form of nozzle-diffuser, the conventional plot of Residuals. Mean distributions of axial wind speed and axial pressure constant within the nozzle-diffuser section of the best nozzle. Streamlines of the system with the best nozzle. The pressure zone within the outlet of the system offers rise to an additional intense suction within the channel leading to the rate rise at the throat. Flange angle to research the influence of finish projection angle, angles of 2.5, 5, 7.5, 10, and 15 were thought of because it is discovered in, the modification within the projection angle slightly affects the number of flows passing through the channel. However, the projection with an associate degree angle of 5 shows the most effective performance. In this study, the performance of the INVELOX system was investigated by analyzing the pure mathematics of the nozzle-diffuser section. Some geometrical changes were applied, together with changes within the nozzle length, diffuser length, diffuser gap angle, and additionally commutation the round shape nozzle with the best one and adding the exit projection. Then, efforts were created to research the peak and gap angle and also their effects on flow characteristics and the channel's ability to extend the flow speed, the most findings of the primary part of the simulation are often summarized as follows: Increasing the nozzle and diffuser length or the diffuser angle, as long because the separation within the channel flow is avoided, will increase the channel potency; commutation the round shape nozzle with the best nozzle considerably affects the flow and flow stream through the channel. The addition of the exit projection well will increase the flow speed through the channel, however, dynamically its angle contains a slight impact on the flow increment. [5] Investigate the pressure and velocity contour of two INVELOX models where model 1 is a basic INVELOX type model where studies hadn't changed any geometry of model 1 and studies had modified model 2 to increase the velocity at venturi section and pressure drop at funnel section to increase the overall efficiency of INVELOX system, The velocity of model 1 get 10.42m/s and in model 2 get to 45.5m/s and focus on pressure drop then model 1 get -1.722×10^1Pa and model 2 get -6.938×10^2Pa It has noticed that model 2 gives the better results than model 1 I happens just because of the modification of INVELOX model, In model 2 instead of intake hopper they placed the VAWT system and attached the propeller fan to VAWT shaft the result of this arrangement is when vertical windmills blade will rotate from outer wind power the propeller fan will also rotate because of this propeller fan will suck the air from outside environment and create the pressure drop and also increase the airflow rate inside the funnel of INVELOX , The methodology of studies includes the modelling of INVELOX system and CFD analysis of both system the solid works is used for modelling and Ansys is used for CFD analysis, studies also analyze by placing the multiple wind mill turbine inside the venturi section of model 2 the results includes the (1)Velocity distribution, (2)Velocity comparison and (3) Pressure distribution. Velocity distribution is analyzed for both models and the inlet velocity for models is 6 m/s for each one of them. Model 1 gives the 10.42 mt /s wind velocity at venturi section and in model 2 the wind velocity obtained is 45.5 m/s, the results shows that model 2 gives the significantly more amount of wind velocity compared to model 1. Velocity comparison studies the wind velocity in model 2 at its different wind turbine stages, here three wind turbines are placed inside the venturi section where intake wind speed is considered as 6.6m/s and at the first stage of wind turbine it gets to 41.44m/s; venturi speed on second stage remains 20.77m/s & venturi speed on third stage of wind turbine remains 3.86m/s. In Pressure distribution, result the pressure drops occurs in model 1 is -1.77×10^1Pa and in model 2 the pressure drop is -6.938×10^2Pa which is comparatively huge respect to model 1 pressure distribution results. Also, the power generation in model 1 is 1825.52W and in model 2 it is 93.15×10^3W. Final conclusion comes to increase the overall efficiency of INVELOX system by first increasing the mass flow rate of air and second is increasing the pressure drop across the turbines. [6] Conducted the study to analyze by modifying the geometrical parameter of INVELOX system according to that changes, how the output results are varying, Studies noticed that the intake area of INVELOX and venturi cross section area has most important effect on the speed ratio, speed ratio(SR) is the ratio of average velocity of wind at venturi section to the incoming wind velocity, and the funnel height and air velocity have minor effect on output results. After the selection of appropriate geometrical dimensions, velocity increases up to 1.9 and at the final stage they placed the HAWT at the venturi section to get the power generation data. CFD analysis of all possible model is done by ANSYS. Results includes the analysis of important geometrical parameter of INVELOX as follows effects of venturi cross section area, effects of upper funnel height, effect of upper funnel, lower diameter, effect of inlet height, Effects of venturi cross section area. For this analysis the inlet area is kept constant and the venturi cross section area has gradually changed respect to the inlet area, after analyzing each value of venturi section which is possible, the maximum speed ratio (SR) achievable is 1.7 according to the Effects of the upper-funnel height. By observing this parameter the recirculation zone in INVELOX can be decreased and also can achieve the good speed ration, Here the inlet height is kept constant and funnel height is considered to be 27, 30, 32.5, 35, 40 and 45ft as the funnel height increases, the amount of air entering the INVELOX and also the amount of air escaping the INVELOX is decreased. However, the variations of the Venturi mass flow rate and the SR are not so intense i.e. ($1.68 < SR < 1.78$). Effects of the upper-funnel, lower diameter (D_d). By increasing the lower diameter of the funnel it increases the pressure drop studies and performed the numerical simulation for various lower diameters $D_d = 8, 6, 4$ and 1 ft after simulation the results shows that by decreasing the lower diameter, the speed ratio will increase, for instance, at the wind speed of 6.7 m/s, a 2.4% increase in the SR has occurred at $D_{down}/D_{up} = 0.025$, relative to the $D_{down}/D_{up} > 0.1$. Effects of the inlet height, H_1- In this analysis the other parameters are kept constant and only the inlet height gradually changes, it has been noticed that by increasing the inlet height; the amount of inlet air will increase and as a result the speed ratio will increase, increasing the ratio of inlet height to the overall height from 0.54 to 0.6, has resulted in a 15% increase in the SR. [7] Fluid flow characteristics like liquid & gas, which plays an important role within the modern engineering field having in depth application within the industries. The investigation of fluid flow and its characteristics is important to perform experimentation with engineering studies. Computation of rate through a pipe is completed with the distinction of pressure head accessible at the cross-sectional space of the pipe. The meter that performs the aforementioned computation of fluid flow is termed a venturi-meter. Venturi-meter finds helpful in plumbing, fluid line, automotive carburetor, rock oil chemical industries, etc. during this experimental study, associate degree investigation is administered in a very fluid engineering work equipped with a facility for flow standardization. Venturi-meter and Orifice-meter is used to live discharge coefficients for the fluid thought of within the experiment. The impact of angles on fluid characteristics is studied by modelling through the process fluid dynamics approach. Fluid flow within the venturi-meter is simulated with a gradual flow within the k-epsilon model.

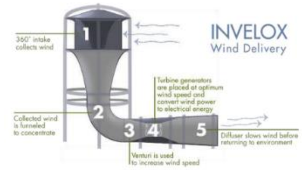


Fig. 10.

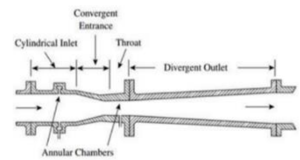


Fig. 11.

$$P_1/g + V_1^2/2g + z_1 = P_2 / g + V_2^2 / 2g + z_2$$

The equation is predicated on the belief that the flow is stable, unstable, and also the flow and uniform speed profiles occur at the pressurized region.

$$Q_m \infty \sqrt{P}$$

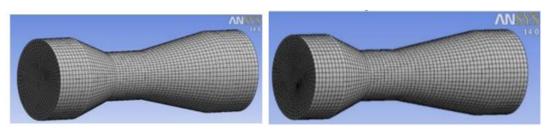


Fig. 12.

This relationship is named Bernoulli's formula. In Tao's explanation, Bernoulli's formula is the rate of a single-phase fluid mass is proportional to the root of the differential pressure in venturi-meter. Venturi action could be a method with iterations to formalize the ultimate pure mathematical model. During this study, the iteration is completed with the convergent and divergent angles of venturi to urge the expected style. No-slip wall condition for the mass and momentum considering wall roughness as swish.

Table 1

Type	Venturi Angles		Coefficient of Discharge (C_d)		Change (%)
	Θ_c	Φ_d	Experimental Method	CFD Analysis	
1	21	9	0.9983	0.9443	5.40
2	20	11	0.9079	0.8283	8.71
3	21	7	0.8283	0.8887	6.80

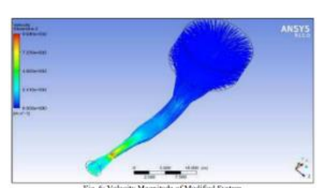


Fig. 6: Velocity Magnitude of Modified System
Fig. 13.

The experimental investigation has been administered on the setup facility for venturi-meter styles as mentioned within the section of the procedure. This setup includes 2 pipelines of 40mm and 25mm diameter placed in parallel and stuck to the soft-cast steel stand. The table shows the amendment within the worth of discharge constant for the scientific method and CFD analysis. In this study, completely different geometries of venturi-meter models are measure & analyzed and compared with the experimental fluid work setup results. Overall calculation and simulations are measured by performing the study of convergent and divergent angles of Venturi and their impact on the discharge co-efficient. [8] INVELOX could be a wind delivery system appropriate for alternative energy harnessing. One among its innovative options it's capability of incorporating multiple turbine generator systems within the venturi section. Its initial innovative feature is that the elimination of tower-mounted turbines. Secondly, INVELOX captures wind to flow through associate degree omnidirectional intake or multi-unidirectional intakes, so there is no further need for any yaw management system to orient the turbine. Third, it accelerates the flow among a shrouded venturi section that is afterwards swollen and unleash into the close atmosphere through a diffuser. The Multiple turbine INVELOX Technology system is sculpturesque during this work. It captures, accelerates, concentrate and measure the wind velocity at 3 regions that are specific for the essence of the Multiple turbine INVELOX Technology system approach to alternative energy generation.

Bernoulli's Equation,

$$P/2g + V^2/2g + z = \text{Constant}$$

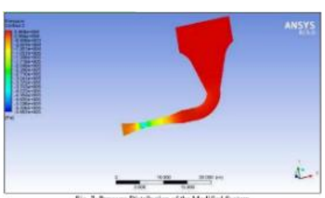
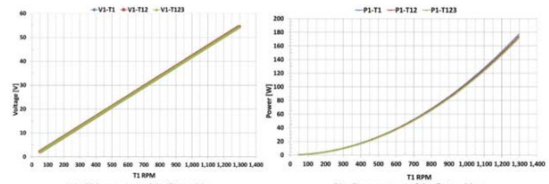


Fig. 7: Pressure Distribution of the Modified System
Fig. 14.

The fundamental characteristic of the Multiple turbine INVELOX systems is that it captures an oversized portion of free stream flow of air larger than 1 m/s. The basic calculation for Multiple wind turbines is done by placing the turbines within the venturi section of the INVELOX system. The dimensions and pure mathematics of unidirectional INVELOX model. This model uses a double nested cone construct with 360º wind intake capability. This unit is scaled to suit a 1.8 m to 1.22 m diameter turbine at the Venturi location, and to be erected to a height of 18m. As a result, INVELOX which does not possess rotor or hub mounted, the top of the tower is measured from the middle of the intake to the bottommost level. If the free stream wind speed is 4.51 m/s, the speed at the situation of the rotary engine is going to be adequate 28.32 m/s. The intake consists of 2 nested cones, the highest cone is that the guide directive wind into the lower cone. The intake of the INVELOX tower was additionally fitted with four fins orienting at a 45-degree angle. In reference to the data, it concludes that Omnidirectional Multiple turbine INVELOX System captures wind from every direction. In Multiple wind turbine's INVELOX System, the increment in multiple turbines within the venturi section for additional power harness.



(a) Voltage output of the first turbine (b) Power output of the first turbine
Fig. 14.

[9] INVELOX is a wind delivery system appropriate for wind power generation. One among its innovative options is its capability of incorporating multiple turbine generator systems within the Venturi section. INVELOX captures wind to flow through an omnidirectional inlet or multiple unidirectional inlets and thereby there is no need for external or internal yaw management to orient the turbine. While the turbine trade has created major advances in increasing the capability by increasing the rotor diameters and also the tower heights, nonetheless the low capability factors, excessive time period, and O&M prices are major challenges in creating wind reasonable and reliable. These problems have slowed wind generation from reaching its full potential. Current wind turbines are typically subjected to excessive time period because of the very long time needed to take care and repair blades, yaw, pitch management, or generator failures at the highest of a hundred to a hundred and 60m tall towers. The key elements of INVELOX system are: (i) intake, (ii) boosting wind speed by a Venturi section, wind energy conversions system, and (iii) a diffuser.

The main characteristic of the INVELOX system is that it collects a major portion of free stream flow and therefore in nearly any free stream location with flow bigger than 1 m/s. This inflated mass rate carries energy per unit mass from the free-stream that for inviscid fluids remains unchanged until it interacts with the rotary engine within the Venturi section. INVELOX passively converts the present kinetic and potential pressure energy of wind to higher mechanical energy that may additionally be effective to regenerate the mechanical rotation of a rotary engine. The objective of this experimental work is to demonstrate the performance of INVELOX with multiple turbines put in its Venturi section. An active methodology is devised which is concerned with intensive testing in one among the 2 fielded units of the INVELOX wind delivery system. The tower height is 18.3 m and also the diameter of the Venturi section is 2m. Pressure rates are measured at the free stream and right before the rotary engine within the Venturi section. Voltage and Power output for 2 turbines are once operated at the same time.

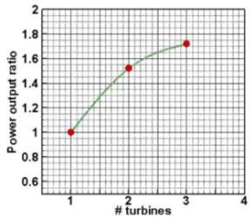


Fig. 15.

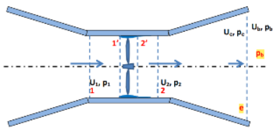


Fig. 16.

In the above data, we tend to provide, a theoretical background explaining the operation of INVELOX and its performance with 3 wind turbines placed in within the Venturi section. It's been shown that the extraction of energy depends on the inflated mass rate through the system controlled by the omnidirectional intake and also the external flow that sets up the backpressure. Thus, the mass rate through the system could be a result of the interaction between the inner and also the external flows. This investigation additionally incontestable, for the primary time, INVELOX possess the capability to accommodate up to a few turbines with none substantial modification within the infrastructure. [11] A windmill is a mill that transforms energy. Wind energy conversion systems have been around for over 3000 years. Originally, wind energy was used to start a function such as moving boats using sails, cooling homes by circulating outside air, running machinery on farms and even small manufacturing plants. INVELOX is a wind capture and distribution system that provides greater engineering control than ever before. Whereas conventional wind turbines use massive turbine-generator systems mounted on top of a tower, INVELOX, on the contrary, diverts wind energy to ground generators. Rather than grabbing bits of energy from the wind as it passes through the blades of a rotor, INVELOX technology captures the wind with a funnel and directs its flow into a passageway that passively and naturally accelerates its flow. This wind energy flow then drives a generator safely and economically installed at ground or underground levels. The performance of the system has been verified with the most recently measured field data. Studies made INVELOX model and done some changes on its outer geometry and analyze that model, CREO is used for modelling INVELOX, following table shows all the output results respect to the inlet velocity.

Table 2

Actual Wind Speed (m/s)	Velocity in INVELOX (m/s)	Power in INVELOX (watt)
1	1.724	2.796
2	3.495	24.777
3	5.272	85.043
4	7.074	205.517
5	8.885	301.11

[12] Today, electricity plays a vital role in every field. The main scope of this project is to overcome the challenges of existing windmills. However, in this project, the propeller rotation was increased four times for the surrounding wind speed. Therefore, any gain in kinetic energy of a fluid due to its increased velocity through a contraction is offset by a decrease in pressure. Thus, electricity is generated. Well, a windmill is a mill that converts wind energy into rotational energy by means of vanes called sails or blades. In this project they took some assumptions 1) Total area is enclosed. 2) The reaction force to the wind blade is ignored. 3) the propeller speed is 4 times more efficient than other wind turbines. 4) In this type of wind turbine, the steering system is completely ignored. The working principle of this windmill is mentioned below. When wind flows, it enters into main nozzle. The main nozzle's function is to collect air from all directions. Even if the wind direction changes, the main nozzle collects it and sends it to the collection tank. After passing through the main nozzle, the wind speed increases slightly. It enters the throat through the converging nozzle. In the converging nozzle, the air velocity increases rapidly. Whereas in the throat part, pressure decreases and speed increases due to the venturi effect. The high-speed air drives the propeller, which in turn rotates the propeller shaft and exits through the diffuser. The diffuser reduces the wind speed. The propeller is connected to the generator. So, electricity is produced by the generator. This electricity is stored in batteries (lead acid). Lead acid batteries are the most reliable form of energy storage because they can go through thousands of charge and discharge cycles without significant wear and tear. When a fluid flows through a constricted portion of a pipe, it shows venturi effect that means reduction in the fluid pressure. Here venturi effect works as a jet effect because of a funnel, it increases the velocity of the fluid and decreases cross sectional area and static pressure respectively. The main goal of this project is to overcome the difficulties of conventional windmills. Some of the intricacies of conventional windmills like the rotation of the propeller depends on the wind speed of the environment. However, in this project, the propeller rotation is increased four times for the wind velocity in the environment. So, save energy and save lives. [10] INVELOX wind turbine, another idea in outfitting wind energy, has re-established the conduit wind turbine idea and attempted to break the boundaries to offer better execution with lower costs. The motivation behind this examination is to address the presentation of INVELOX unit introduced in Manjil dependent on IEC 61400 standard, the primary INVELOX wind turbine in IRAN. Suggestions for future work and advancement are examined. First wind flow was principally utilized as wind catchers of boats and cooling for houses. The wind energy industry couldn't offer legitimate execution with reasonable expense because of these hindrances. INVELOX innovation that has been popularized and acquainted with market recently can address most of pipe turbine issues and make wind energy a viable source contrasted with petroleum derivatives. The word INVELOX is picked for increment in velocity and X to show duplication. In this article, INVELOX has been established with speed proportion of 1.7, 19.2m height, 23m length, 1 m blades

and a diffuser pointing towards South-West. The measuring system contained two speed and direction sensors within the venturi. Also, the speed of the generator was measured. Fig. four is that the weather map comparison diagram of field knowledge with the info of Sana's lookout within the given amount. As clearly determined two diagrams are consistent. This comparison was created to substantiate the wind direction knowledge of the rotary engine within the next steps once putting in generator. As expected, the air speed was increased to 1.7 times, and the turbine indicates more than 1000 revolutions per minute. Then the 300 W generator was replaced with a 10 kW to get better output. Fig. five shows a group of information conducted in January and Gregorian calendar month 2016. the info set represents the rise in air rate within the Venturi duct of the system that was on top of the calculable worth of one.7. There's a 30-metre-high hill among the 50-metre vary of the positioning in North-West and North that restricted the wind ensue these directions. Fig. eight embodies the INVELOX power curve supported measuring procedure of IEC 61400 standards, that is in keeping with power outputs in East - North East, the most effective wind direction in line with diffuser position. The collected knowledge shows that, even once the rotary engine was placed within the venturi section, the speed roughly doubled. The power curve and execution of an INVELOX wind turbine was introduced dependent on IEC 61400. The framework had 1-m cutting edge with speed amplification of 1.7. The INVELOX wind turbine was tried in all wind directions and the deliberate information affirmed the Omnidirectional admission can catch wind in 360 degrees. Also, information showed that the turbine execution was improved from 300 watts to 3600 watts because of sped up and upgraded power coefficient when turbine was introduced in the Venturi part of INVELOX. The cutting-edge cut-in and evaluated speeds were two elements restricting turbine performance. It is prescribed that a superior planned sharp edge to be utilized later on tests. The power coefficient acquired from field information concentrate on INVELOX is generally equivalent to 46% which is a lot higher than manufacturing plant indicated Cp. This improvement from 26% to 46% might be identified with channel execution and its communication with the sharp edge as indicated by static tension contrasts through the pipe.

2. Conclusion

This paper presented an overview on characteristics of performance, structure and behavior of INVELOX wind turbine.

References

[1] Ding L, Guo T. Numerical Study on the Power Efficiency and Flow Characteristics of a New Type of Wind Energy Collection Device. Applied Sciences. 2020; 10(21):7438.

[2] Golozar A, Shirazi FA, Siahpour S, Khakiani FN, Gaemi Osguei K. A novel aerodynamic controllable roof for improving performance of INVELOX wind delivery system. Wind Engineering. 2021;45(3):477-490.

[3] M. Anbarsooz, M. Amiri, I. Rashidi, "A novel curtain design to enhance the aerodynamic performance of Invelox: A steady-RANS numerical simulation," Energy, volume 168, 2019, pp. 207-221.

[4] S. Rasoul Hosseini, Davoud Domiri Ganji, "A novel design of nozzle-diffuser to enhance performance of INVELOX wind turbine," Energy, volume 198, 2020, 117082.

[5] Gohar GA, Manzoor T, Ahmad A, et al. Design and comparative analysis of an INVELOX wind power generation system for multiple wind turbines through computational fluid dynamics. Advances in Mechanical Engineering. April 2019.

[6] Anbarsooz, M., Hesam, M.S. and Moetakef-Imani, B. (2017), Numerical study on the geometrical parameters affecting the aerodynamic performance of Invelox. IET Renewable Power Generation, 11: 791-798.

[7] Shinde, Pushpak & Chaudhari, Rahul & Patil, Prayag & Marathe, Satish. (2020). Modelling and Simulation of Venturi Parameters in Relation to Geometries and Discharge Coefficient with Computational Fluid Dynamics Technique. International Journal of Engineering Research and Technology.

[8] Anand Kumar Labhubhai Solanki; Brijesh D. Kayasth; Hardik Bhatt, "Design Modification & Analysis for Venturi Section of INVELOX System to Maximize Power using Multiple Wind Turbine."

[9] Daryoush Allaei, David Tarnowski, Yiannis Andreopoulos, "INVELOX with multiple wind turbine generator systems," Energy, volume 93, Part 1, 2015, pp. 1030-1040.

[10] Khatibzadeh, Ahmadali & Farahpour, Hengameh & Radfar, Payar & Saniei, Pooya. (2017). INVELOX Wind Turbine Power Curve Modeling based on Field Data in Manjil, IRAN.

[11] Dhananjay Kadlag, Bhor Sushma, Bangar Vishal, Rajgude Bhagyashri, Doke Prafull, INVELOX Windmill."

[12] R. Karthikeyan, V. Nagendrakumar, M. Mukilvendhan, E. Narenthiran, P. Soundhirajan, "Economic Windmill by Using Venturi Effect."