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Microcontroller Based Portable Anemometer for Wind Monitoring System

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Abstract: Weather monitoring and forecasting system plays an important role nowadays in all the aspect of science, trade and other fields not limited to the field of cultivation, farming, fishery, naval trade, shipping, military operations, air navigation etc. Wind speed and wind direction is one of the most vital weather variables like moisture, pressure, temperature, density, rain forecast, solar radiation, clouds, air masses, fronts and storms. In this paper, a low cost PIC16F887 microcontroller based portable wind speed and wind direction monitoring system called an anemometer is designed & experimented. The designed anemometer is divided into two parts namely mechanical and electrical parts. Both parts are developed, designed and tested in this research work. Wind turns the cup of Anemometer and produced mechanical energy that converted to electrical energy or signal. The electrical signal or pulse intervals determine by the microcontroller and generate consequence pulses to find out the wind speed. The programming codes inside the microcontroller helps to extract the voltage drops measured from a potentiometer connected to the mechanical part of Anemometer and intellect the wind direction precisely. A lucrative 16x2 liquid crystal display (LCD) is used to display the wind speed and direction.

Keyword: Microcontroller; Anemometer; Wind monitoring system

I. INTRODUCTION

Weather constantly vicissitudes at its own way of nature greatly stimulus the daily attitudes and actions of human being such as, farming, angling, transport, armed operations etc. But over the centuries, some actions of nature such as floods, tornados, earthquakes, cyclone etc. have abolished valuable assets and many peoples and animals died.

The weather monitoring sectors are laboring hard to track and monitor the climate variations [1]. Considering these issues, it will be very helpful to use a portable wind speed direction and monitoring system in every small area like rooftop of

the house or also in a rural area which can detect the weather condition in a short time and aware the concerned authority. Normally maximum weather monitoring sector customs numerous climatologically devices with different type of sensors to detect climate changes [2]. The overall system can monitor weather changes by sensing atmospheric compression, temperature, wind speed etc. But edging the sensors to microcontroller is hassle-free, cost effective with simple circuits. Since the variation of wind speed is daylight [3,4], the total lifespan cost of the wind speed and direction monitoring system can be minimized. Winds uninterruptedly moves vertically as well as horizontally in the earth surface. Vertical movements of the wind speed can be maximum ten times of that of horizontal movements [5]. To calculate wind speed different types of equipment is used. One of the important apparatus is wind vane, that directs the way of wind are coming from, first used in 48 BC in Athens [6]. To measure the wind speed, an Anemometer is used, and Anemometer is come from the Greek word 'anemos'like the word 'wind'. The Mayans used a pressure plate anemometer that contains a small balls light in weight that released from a jar or basket and were puffed downwind in between 1200 to 1400 BC [6]. Italian architect Leon Battista Albert invented the first mechanical anemometer in 1450.This anemometer was a plain hanging plate in which a board vibrated along an advanced pressure forced into the wind vane [7,8]. In 1805, an Irish hydrographer sir Francis Beaufort constructed a wind force scale called Beaufort scale, primarily used in naval activities [6]. In 1846, Irish astronomer Thomas R. Robinson invented the cup anemometer that had four cups [9]. A cup anemometer consists three or four hemispherical cups in top of the arms centralized a single arm or bar. The single arm that is mounted with the other four or three arms is connected to a bearing to rotate following the wind direction [10].Airs set the compression on cups whereas blowing in perpendicular way of direction with revolving the arms in proportional to the wind speed [11]. Furthermore, a modest tinny metallic sheet is mounted at maximum or pick point of the structure with less frictional comportment to passage transversely the radial alliance namely wind vane which follows the wind path to monitor the direction or pathway of wind. [11,12]. Instinctively, some anemometer has propeller connected to the front of device or last portion, so wind vane contains of propellers and a pivoted axis [13].

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At present, marketable algorithms or control part of wind speed and direction monitoring system are like feedback included the blade pitch outlined by pitch controller based on proportional-integral (PI) that can receives input signal of possible error in speed measurement system generator[14]. Furthermore, this kind of modern controller characteristically engage in separate and specific control of the pitch and some time it can be initiated based on place encoders as well as strain gauges tousing generator speed of the system accordingly[14].In this work, a portable microcontroller-based wind speed and direction monitoring system has been designed as well as experimented. The main difference with the existing methodology and the proposed anemometer is the control unit. The control unit of this anemometer is fully microcontroller based. The main contribution of this research is to minimize the cost and make the device portable as well as simple. Here, a modest electronic circuit is premeditated to fix real time wind speed and along with direction. A MOC3021 optocoupler is used to convert the mechanical energies from moving cups of anemometer to electrical signals. The output of the optocoupler is transferred to the input of the PIC16F887 microcontroller. The programmed code of the microcontroller detects the pulse intervals of the input signals and measures the wind speed. The ratio of the voltage drops in the potentiometer connected to the bottom of the wind vane and the reference voltage coded to the microcontroller detects the wind direction. Practical data collected from the designed prototype is compared with the data of Bangladesh Meteorological Department [4]. Finally, project cost analysis also done that shows the proposed design is cost effective.

Table. 1 Different types of common anemometer

Sl. No.	Types of Anemometer	Advantage	Disadvantage
01	Cup Anemometer	Self-directed following the winds, don't need to put extra pressure.	Susceptible to frosting weather.
		Capable of lasting in rough climate	Sometimes the initial velocity is higher than the regular velocity.
02	Hot Wire Anemometer	Long lasting than other anemometers	Unproductive where temperature varies fast
		Have low starting threshold	Can spoiled by the dirt
		Delivers error-free reading	
03	Sonic Anemometer	Not exaggerated by frosting	High Cost
		Weather resilient	Birds can cause false reading
		Not affected in rough weather	
04	Windmill Anemometer	Used for high wind velocity	Not self-directed towards the wind
		Lasts longer	Rotating parts of the windmill may deteriorate for aging
		Capable to handling heavy-duty purpose	Initial speed is high.
05	Pitot Tube Anemometer	Suitable for high wind speeds	Appropriate for low wind speed area
		Have no rotating parts so doesn't deteriorate easily	Not capable for irregular wind velocity
		Rapid response rate	

II. ANEMOMETER

At present various types of anemometer are available. Anemometers can be classified in two categories one, that can measure the wind speed and second, that can measure the wind pressure, since there is a close interrelation to measure both the wind pressure and speed all anemometer can calculate both the speed and pressure at a time [15]. Most common types of anemometer including common advantage and disadvantages are listed in Table 1.

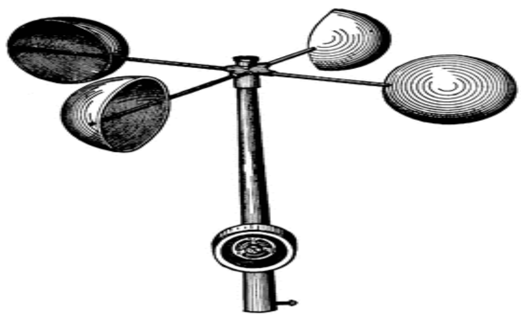

Fig. 1 Robinson cup anemometer

Literature review shows that cup anemometer invented in 1846 and has four cups that reflected in the German instrument

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"Schalenkreuzanemometer", in Danish like "skålkorsanemometer". Figure 1. Shows a Robinson cup anemometer with four cups. The building blocks in these languages are "Schale"="skål"="bowl"/"cup" and "Kreuz"="kors"="cross", and the last part of the word indicates that the cup anemometer has four arms [16]. The inventor Robinson supposed that, the speed of the center of the cups are exactly one third of the total wind speed strikes to the cups and the bearing friction that provided to move the cup arms can be ignored. The ration of the wind speed and the cup speed is known as 'factor'. In 1926, a study discovered that the factor wide-ranging between 2 and 3, though its differed instrument to instrument. It is also revealed that; linearity is better than the higher ratio of the cup radius and the arm length.

Since three cups anemometer response rapidly than the four cups anemometer corresponding the wind speed, it also proves that the three cups anemometer is better than the four cups anemometer [17]. The calibration of the cup anemometer can be according to the equations [17-18]:

$$S = \frac{U-U_0}{l}\, ms^{-1} \qquad (1)$$

Here,

S = Angular velocity of rotor

$U = Wind\ speed$

$U_0 = Starting$ wind $speed\ to\ start\ cup\ anemometer$

$l = calibrationdistance$

III. SYSTEM DESIGN OF PROPOSED CUP ANEMOMETER

As mentioned in earlier part of this paper, the proposed cup anemometer designed into two segments, electrical and mechanical. This section will cover the mechanical design. Figure 2 presents the proposed design of cup anemometer. Left part of the Figure 2 shows all the individual parts. The device consists three cups mounted with three individual arms centered in a bearing. This bearing connected the bottom portion of the device by a metal body. An optocoupler is connected beside to the bearing. Wind moves the cup of anemometer, cup will turn the bearing, from the bearing opt coupler will get the mechanical signals and convert it to electrical signal that will be inputted to the microcontroller and the microcontroller will calculate the wind speed. Right part of the Figure 2 shows the measurements of the protype. Each cup is 5.08cm, each arm is 12.7cm, angle of each arm is 120 degree, and the metal body is 60.96cm. The proposed design of wind vane for wind direction measurement unit is shown in Fig. 3. Left part shows the four-part wind vane, vertical shaft, contact and potentiometer of the wind direction monitoring unit and right part presents the measurement of each part depicted in the left part. Wind vane is 15 cm, vertical shaft is same as the body of cup anemometer 60.96 cm, back support rod of the vane is 20 cm long. Wind turns the wind vane and a certain amount of voltage drop will occur to the potentiometer, then the output of the potentiometer as a dropped voltage convert to electrical signal and fed to the microcontroller, finally the microcontroller will determine the direction and display to the LCD display.

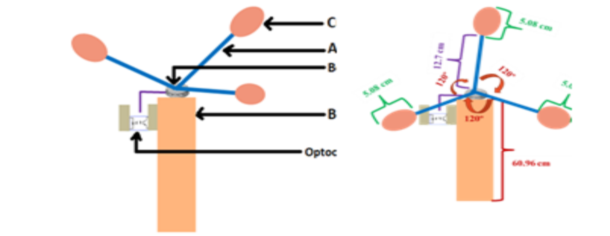

Fig. 2 Proposed design of cup anemometer

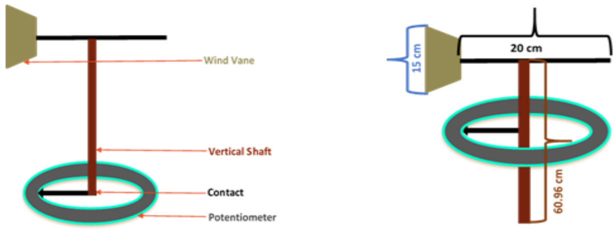

Fig. 3 Proposed design of wind vane

IV. OPERATING PRINCIPLE AND CALCULATION

Figure 4 shows the operation of the proposed cup anemometer for wind speed and direction measurement operations in block diagram. As it shows, wind turns both the cups and wind vane at a time. Three cups start moving

By centering the arms locked in the bearing. The moving cups also starts to transfer signals to the opt coupler. This transferred signal received by the infrared ray (IR) light emitting diode (LED) of the optocoupleras shown in Fig. 5. Then the IR LED produces infra-red light and emit to the photo transistor of right-side circuits. The intensity of the IR LED directly controls the photo transistor. The output of the photo transistor of the optocoupleras directly fed to the microcontroller input. Cup of the anemometer moves circularly and cross the radius path of the circular way having 12.7 cm or 0.127 m radius of the circular way forming by the cups. Let the radius of the circular path is R then the circumference can be present by the following equations.

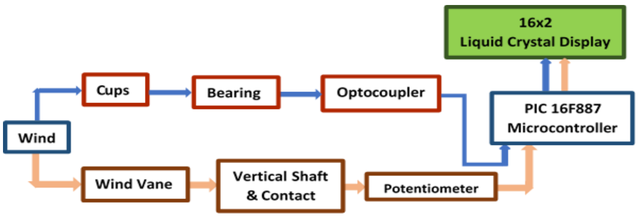

Fig. 4 Block diagram of the designed cup anemometer for wind speed and direction measurement

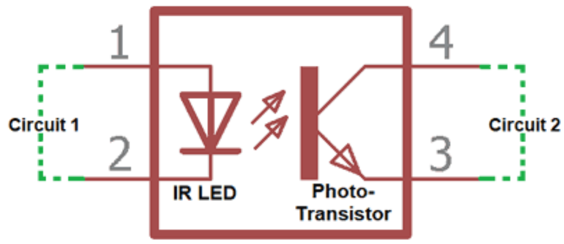

Fig. 5 Schematic diagram of an Optocoupler

$$Circumference, C = 2\pi R \qquad (2)$$

$$Here, radius, R = 0.127\ m \approx 0.13\ m$$

Now, from equation (2), $Circumference, C = 2 \times 3.1416 \times 0.13 = 0.816816\ m \approx 0.82\ m$

When the cup set moves circularly, then cuts the optocoupler signal, as a result optocoupler generates one single pulse for one complete rotation of the cup set. Let the circumference of the circular path is 'C' Equation 3 is used to measure the wind speed of the proposed cup anemometer.

$$Wind\ speed, S = \frac{C \times N}{t}\ ms^{-1} \qquad (3)$$

Here, $C = Circumference\ in\ meter\ (m)$

$N = Number\ of\ pulse\ generates\ by\ optocoupler$

$t = time\ in\ second\ (s)$

PIC 16F887 Microcontroller is a flash based 8-bit CMOS controller [19]. Microcontroller receive signals from the optocoupleras and counts the intervals of the electrical signals and calculate the wind speed. In similar way wind vane turns by wind and the vertical shaft, contact connect with a $10\ k\Omega$ potentiometer. Each voltage drops in the potentiometer is 0-5V, and 0-360 degree for a full rotation of the contact to the potentiometer measured by the microcontroller to determine the wind direction. Relation between output voltage of the potentiometer and the wind direction can be measured by the Eqn. 4. and the output voltage of the potentiometer is fed to R_{A0}pin of the microcontroller.

$$Wind\ Direction, D = \left(\frac{V_{out}}{V_{in}} \times 360\right)^{\circ} \qquad (4)$$

Here, $V_{out} = Droped\ voltage\ in\ potentiometer = 0V - 5\ V$

$V_{in} = Reference\ voltage\ of\ potentiometer = 5V$

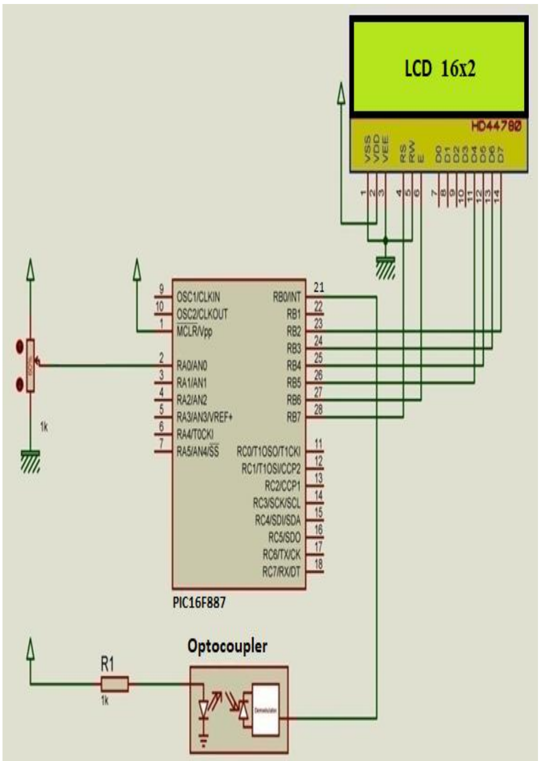

Fig. 6 Circuit diagram of the proposed anemometer

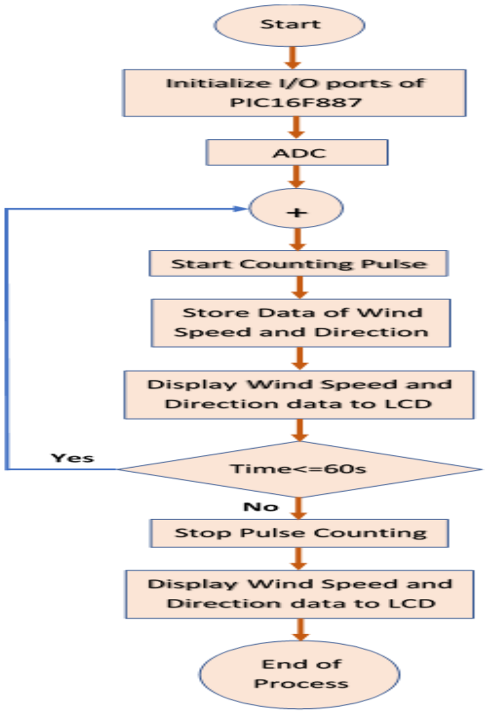

Fig. 7 Microcontroller programming flowchart

Figure 6 shows the proposed circuit diagram, based on this circuit the prototype has been designed. An external +5V voltage source is connected to active the microcontroller, LCD and the optocoupler. MCLR/VPP, 1 number pin of the microcontroller, VDD-2 number pin of the LCD, the open node of the optocoupler is connected to +5V voltage external source. VSS, VEE and RW pin of the LCD are common and connected to the ground. The output of the optocoupler is connected to the RB0/INT, 21st number pin of the PIC 16F887 microcontroller.

The pins of RB2-RB7 of microcontroller are connected to the LCD display. Pin of RB6, RB7 of microcontroller is coupled with the register (RS) and enable (E) pin of the LCD respectively. Figure7 shows the program flowchart of microcontroller. First the microcontroller initiates the input/output (I/O) ports of the PIC16F887, then converts the data analog to digital, after the conversion, microcontroller starts to count the incoming pulses, then the potential data are stored and display to the LCD display. If data incoming is continued within 60s then the process continuously run, if data is not updated within 60s loop, microcontroller will show the previous stored data. Finally, Figure 8 and Figure 9 shows the designed anemometer circuit board, which mainly consist of an LCD display, microcontroller, a 9V researchable battery and implemented hardware design of wind monitoring system respectively. The designed prototype is small and designed for experiments in laboratory environment where natural wind was not available, that's why it was not possible to carry the experiment with natural wind and same environment with the BMD. BMD is the government controlled, commercial meteorological data provider. The intended target was to minimize the cost of anemometer and make the device portable as well as simple. Thus, the error calculation is ignored here. In future, for further improvement, we will

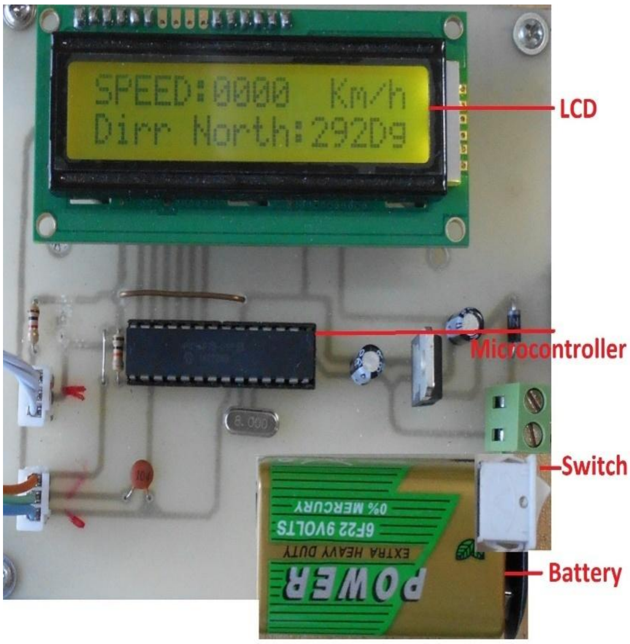

Fig. 8 Circuit board of the designed anemometer prototype

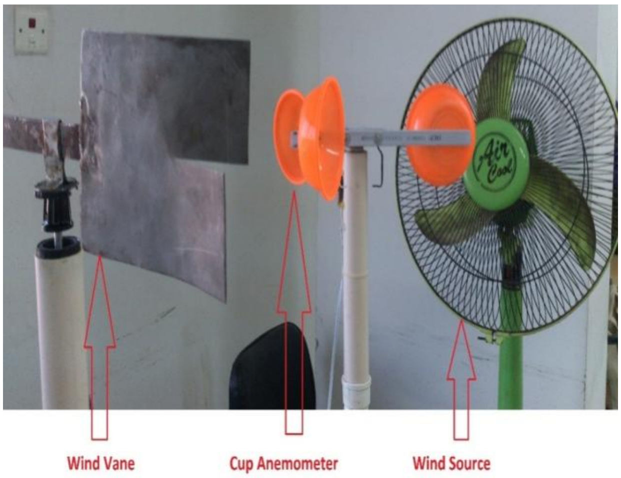

Fig. 9 Designed prototype of wind vane and cup anemometer

V. RESULTS

The outcome results from the prototype are shown in Tables 2 and 3. In addition, the result is compared with BMD data and are presented in Table 4 and 5.Experimented data taken in a day but in different hours at 10AM, 11AM, 12PM, 1PM, 2PM and 3PM. Table 2. shows the wind speed in kilo meter per hour (Km/hr), highest speed found 5.50 Km/hr as well as the number of pulses recorded from the optocoupleras in 60s. Table 3 shows the wind directions in degree (**º**), highest angle found in degree 218**º** as well as the recorded voltage drop in the potentiometer. The experimental wind speed is comparatively low because of using an electric table fan of 75W as wind source. Table 4. presents the respective comparison of BMD anemometer data and the experimented data from prototype. Table 5. Shows the tabular form of both the wind direction data of BMD wind vane and the prototype wind vane. Graphical data of wind speed experimented from the prototype and the collected data from the BMD is shown in Fig. 10, as well as the wind direction angles is shown in graphically in Fig. 11. add error analysis with discussion In both figure the orange color line presents the experimented data and the red color data presents the collected data.

Table. 2 Experimented wind speed from the prototype

Time	Wind Speed (Km/hr)	Wind Speed (ms^{-1})	Pulse (N)
10.00 AM	5.30	1.47	108
11.00 AM	4.50	1.25	91
12.00 PM	5.50	1.53	112
1.00 PM	5.00	1.39	102
2.00 PM	4.50	1.25	91
3.00 PM	5.20	1.44	105

Table. 3 Experimented wind direction from the prototype

Time	Wind direction	Dropped Voltage, Vout (V)	Wind Angle (º)
10.00 AM	South-west	2.99	215
11.00 AM	South-west	3.03	218
12.00 PM	South-west	3.00	216
1.00 PM	South-west	2.99	215
2.00 PM	South-west	3.01	217

Table. 4 Comparison between collected and prototype data of wind speed

Sl. No.	Collected Data Wind Speed (km/hr)	Prototype Data Wind Speed (km/hr)
1	5.09	5.30
2	4.57	4.50
3	5.60	5.50
4	5.04	5.00
5	4.78	4.50
6	5.34	5.20

Table. 5 Comparison of collected and protype data of wind vane

BMD wind vane		Prototype wind vane	
Wind direction	**Wind angle (º)**	**Wind direction**	**Wind angle (º)**
South-west	220	South-west	215
South-west	222	South-west	218
South-west	221	South-west	216
South-west	220	South-west	215
South-west	218	South-west	217

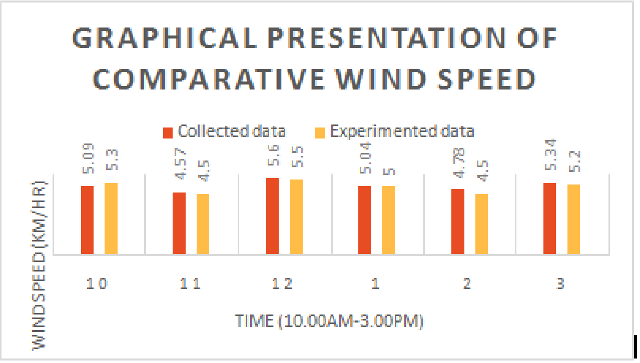

Fig. 10 Graphical presentation of wind speed in kilo meter per hour

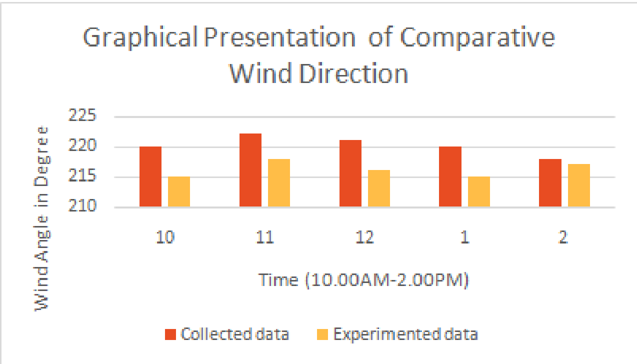

Fig. 11 Graphical presentation of wind direction in angle

Table. 5 Apparatus cost analysis

Sl. No.	Apparatus Name	Quantity	Brand Name/Rating	Unit Price (USD)
	Electrical Part			
01	Battery	1	6F22, 9V	0.30
02	Resistor	2	1 KΩ	2×0.04
03	Potentiometer	1	10 KΩ	1.79
04	Electrolytic Capacitor	2	4.7 µF, 50V	2×0.25
05	Ceramic Capacitor	1	104 pF	0.01
06	Diode	1	1N1147	0.01
07	Optocoupler	1	MOC3021	0.24
08	LCD Display	1	1602 Hd44780	3.73
09	Microcontroller	1	PIC16F887	2.61
10	Printed Circuit Board	1	-	1.00
11	Circuit board shield	1	-	1.00
12	Screw/Shed	1	-	1.00
	Mechanical Part			
13	Wind vane 1			1.5
14	Cup infrastructure 1			1.5
	Total Cost			**15.27**

Table 5 presents the cost of individual equipment that are used in this research work. Cautiously the overall system cost is comparatively lower than any other single device and such as, here the subsystems of the pulse counting process is minimized by the microcontroller which can avoid the complexity of the process analysis. Since this system has been divided into two parts, mechanical and electrical. Individually for electrical part, USD 12.27, and mechanical part USD 3.00 as well as to design full system total USD 15.27 are costed.

VI. CONCLUSION

A portable PIC16F887 Microcontroller based wind speed and direction monitoring system has been designed and experimented. Experimented system calibrated and compared by the data collected from the BMD anemometer. The designed system can provide high grade of portability, also able to serve as a perfect platform to monitor wind speed and direction related data worldwide. In upcoming days, this system can be improvised by interfacing with partial arena as well as countrywide scattered network to monitor overall wind features properly. The system would be a modest solution and has several purposes such as for real-time weather monitoring, determine the climate circumstances, storm warning system etc. Cost analysis done for the both electrical and mechanical part. Total price for the full system of the designed anemometer is USD 15.27, which is the lowest design cost we found in literature review. If it is industrialized the product cost will be further reduced.

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