International Journal of Electrical and Power Engineering 12 (2): 15-19, 2018
ISSN: 1990-7958

To Improve Efficiency of Vertical Axis Wind Turbine Components Evaluation

[1]K. Manikandan and [2]B. Justus Rabi
[1]Department of EEE, Jawahar Lal Nehru Technological University Hyderabad (JNTUH), Telegana, India
[2]Department of EEE, Shri Andal Alagar College of Engineering (SAACE), Mamandur, Tamil Nadu, India

Abstract: Wind turbine brake system plays a very critical role in keeping WT operate normally and safely. This study aims to propose a solenoid based electro-hydro-mechanic braking system for WTs by using IoT. This system includes an intelligent control and monitoring system that commits the braking functionality in a more efficient and reliable way in terms of smooth braking performance, value engineering is a proven management technique that can make valuable contributions to value enhancement and cost reduction in wind industry. The overall estimated savings of the project resulting from the full value engineering study ranged between 20-30% of the element cost; VE is recognized as an effective way to improve the performance of a product with reduction in cost.

Key words: Wind brake, solenoid, value engineering, IoT, safely, intelligent

INDRODUCTION

A wind turbine extracts energy from moving air by slowing the wind down and transferring this energy into a spinning shaft which usually turns a generator to produce electricity. A wind turbine is a rotating machine which converts kinetic energy in wind to electrical energy. The use of wind turbine is important as it is the alternative to other main energy generators. There are two major types of wind turbine determined based on the axis in which the turbine rotates. Horizontal Axis Wind Turbine (HAWT) and Vertical Axis Wind Turbine (VAWT) (Anonymous, 2018). In Wind Energy Conversion Systems (WECSs), the key technologies include wind turbine technology, power electronics technology and system control technology. For the wind turbines, based on the orientation of the rotation axis of the wind turbine there are horizontal-axis wind turbines and vertical-axis wind turbines. The modern engineering design approach can be classified into three subsets, the engineering model, mathematical model and computation model (IEC., 2015).

Efficiency is one of the most important parameters to analyze the performance of a wind turbine design. Efficiency of a wind turbine is expressed usually in terms of flow energy utilization factor and Coefficient of Power (CP) (Froese, 2016). Manual braking is ideal, since, it allows you to stop the machine in all conditions. Drum and disc brakes have been used in a few turbine designs, but most turbines use dynamic or electrical, braking where a big switch opens the connection to the grid or batteries and shorts the three phases of the wind turbine together, a brake controller sends on/off signal to activate/deactivate to DC solenoid (Jee *et al*., 2012). From the experimental results using test bed in the laboratory it is concluded that when initial rotational speed is 600 rpm the mechanical brake could stop the rotating mass in 1.2 sec under solenoid brake (Meeker and McWilliams, 2003).

MATERIALS AND METHODS

Electro mechanical brake: A complete wind energy system including rotor, transmission, generator, storage and other devices which all have less than perfect efficiencies will deliver between 10-30% of the original energy available in the wind. Electromagnetic brakes operate electrically but transmit torque mechanically. This is why they used to be referred to as electro-mechanical brakes. Over the years, EM brakes became known as Electro Magnetic, referring to their actuation method. The variety of applications and brake designs has increased dramatically but the basic operation remains the same. Single face electromagnetic brakes make up approximately 80% of all of the power applied brake applications.The strength of an electromagnet is:

- Directly proportional to the number of turns in the coil
- Directly proportional to the current flowing in the coil
- Inversely proportional to the length of air gap between the poles

Corresponding Author: K. Manikandan, Department of EEE, Jawahar Lal Nehru Technological University Hyderabad (JNTUH), Telegana, India

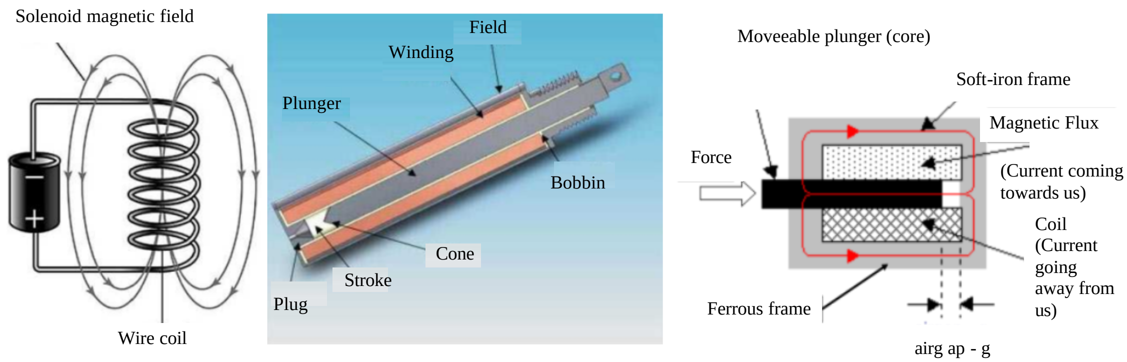

Fig. 1: Solenoid coil model diagrams

In general, an electromagnet is often considered better than a permanent magnet because it can produce very strong magnetic fields and its strength can be controlled by varying the number of turns in its coil or by changing the current flowing through the coil (Fig. 1):

- Force = Kf (constant)×(Number of turns×Coil current $)^2$/(Gap width$)^2$
- The main components of disc brake is thebrake pads, the caliper which contains a piston
- Therotor which is mounted to the hub, hand brake and solenoid

The disc brake is a similar as on abicycle. Bicycle brakes have a caliper which squeezes the brake pads against the wheel. When the brake pedal is applied, pressurized hydraulic fluid squeezes the brake pad friction material against the surface of the rotating brake disc. Friction between the pads and the disc slows the disc down by using push pull DC solenoid.

RESULTS AND DISCUSSION

IoT and value engineering

Internet of things: Various names, one concept:

- M2M (Machine to Machine)
- "Internet of everything" (Cisco systems)
- "World size web" (Bruce schneier)
- "Skynet" (Terminator movie)

Here, we are discussed about IoT based remote control and value engineering the previous one. In IoT remote access, IoT can bridge the gap between a wind farm located several hours or even days away and a local control center with access, so, attendants might adjust switches, software or equipment from a distance. IoT

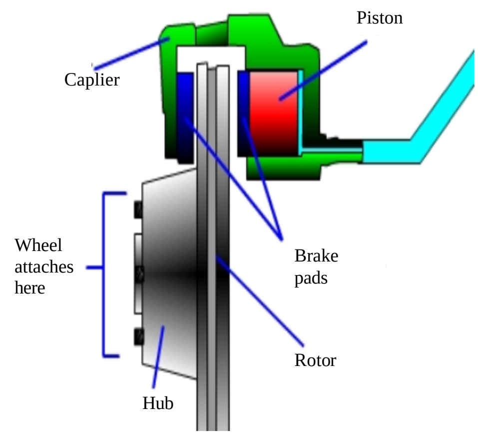

Fig 2: Rotor with brake pads Ref: How stuff works: Ver

gives wind-farm operators control to monitor and regulate much of a turbine's operation no matter how much distance separates the two.

This principle is employed in the magnetic brake for speed control in the wind turbine system. For obtaining the functioning capability of magnetic brake analytically, we need to calculate the power and hence, torque of rotor against the speed of revolution (Fig. 2).

Block diagram: End to end IOT solution development requires a broad range of skills including embedded system design, cloud architecture, application, data analytics, security design and back-end system integration (Fig. 3).

Wind turbine brake system sketch: Nylon spacers, washers and a nut to secure the solenoid (Fig. 4).

Value engineering basic: Structured value engineering job consists of six steps:

- Information phase
- Creativity phase
- Evaluation phase
- Planning phase

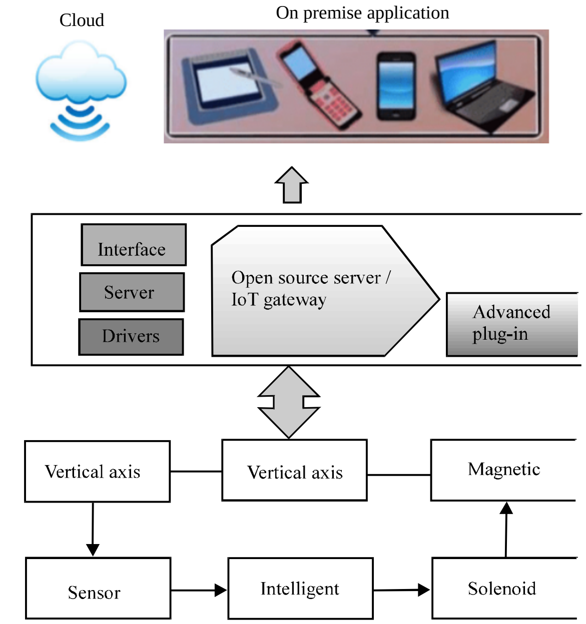

Fig. 3: Sketch of block diagram of the proposed system

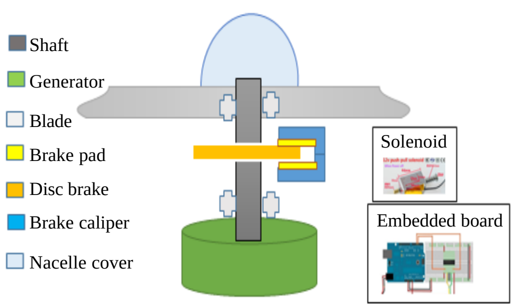

Fig. 4: Sketch of a typical WT brake system

- Reporting phase
- Implementation phase

SWOT: First initiate the SWOT analysis for concept evaluation report (SWOT). To measure the true values in any product ask these questions:

- What is it?
- What does it do?
- What does it cost?
- What else will do the job?
- What will that cost?
- What is the Most Valuable way?

After calculating extended cost, one should perform an ABC analysis. This analysis sorts the cost into three categories by their percentage contribution to the total cost.

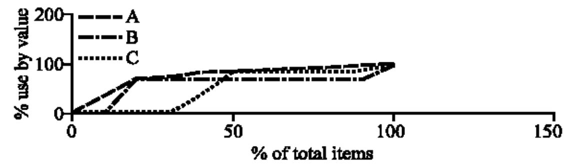

Fig. 5: ABC cost value:a) class items existing design which represent about 10- 15% of the total parts count but account for 70% of the total product cost; b) Class items embedded circuit which represent the next 20% of the total parts count and the next 20% of the total product costs (for a total of 90% and c) Class items Embedded circuit with IoT which represent 70% of the total items but only about 10% of the total cost

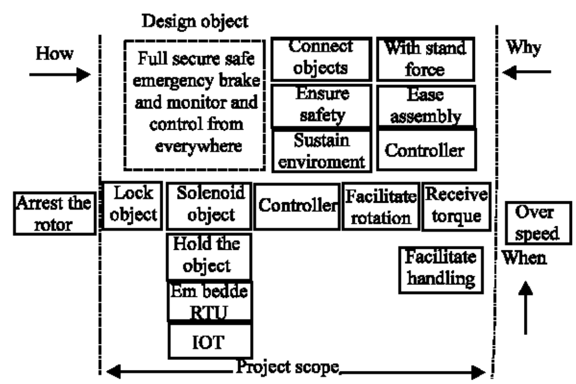

Fig 6: Fast diagram

SWOT analysis: Table 1 contains an example of this type of analysis on a sample electrical assembly (Fig. 5).

Function phase: Specific purposes or intended use of an item (What is this? What is it supposed to do? What else can it do?). It is divided into feature-function matrix, function cost allocation, consolidated feature-function matrix, technically oriented fast diagram and function cost worth analysis (Table 2-4).

Technically oriented fast diagram: Figure 6 shown in technically fast diagram.

Concept evaluation: Predetermined minimum method, parameters considered in the following. Performance, ease of operation, ease of manufacturing, monitor and control for the module, ease of maintenance (Table 5).

Cost benefit analysis: As shown in Table 6 product cast savings.

Table 1: Analysis of sample electrical assembly

Product cost estimation		Information phase: Cost estimation of DC solenoid disc brake in Rs				
Level	Component name	Materials cost	Mfg cost	Cost/piece	Quantity	Total cost
0	DCS disc Brake Assy	-	-	-	1	9.120
1	Embedded Board Assy				1	3.540
2	Embedded Circuits	600	1000	1600	2	3200
2	Distance Tube	10	20	30	2	60
2	Nut	-	-	20	4	80
2	Washer	-	-	10	4	40
2	Bolt	-	-	40	4	160
1	Solenoid Assy				1	1200
2	Solenoid	400	500	900	1	900
2	Power Circuit	-	-	250	1	250
2	Stand	-	-	50	1	50
1	Brake Handle Assy				1	2500
2	Brake Handle	600	500	1100	1	1100
2	Brake Pad	200	100	300	2	600
2	Brake Caliper	500	300	800	1	800
1	Top Link Pin Assy				1	940
2	Top Pipe Pin	400	300	700	1	700
2	Nut	-	-	20	4	80
2	Bolt	-	-	40	4	160
1	Bottom Link Pin Assy				1	940
2	Bottom Pipe Pin	400	300	700	1	700
2	Nut	-	-	20	4	80
2	Bolt	-	-	40	4	160

Table 2: Function level

Product name	Sub-assembly	Component name	Feature	Type function (Use/Sell)	Function: Verb	Function: Noun	Function level (Basic/Secondary)
DCS rotor lock				Use	Lock	Object	Basic
				Use	Withstand	Force	Secondary
				Use	Ensure	Ensure	Basic
				Use	Ease	Safety	Secondary
				Use	Sustain	Assembly	Secondary
				Use	Facilitate	Environment	Handling
DCS rotor lock	Embedded assy			Use	Lock	Object	Basic
DCS rotor lock				Use	Withstand	Signal	Secondary
DCS rotor lock				Use	Ensure	Safety	Basic
DCS rotor lock				Use	Maintain	Gap	Secondary
DCS rotor lock				Use	Facilitate	Handling	Secondary
DCS rotor lock				Use	Ease	Assembly	Secondary

Table 3: Function cost allocation in RS

Component	Component cost	Function: Verb	Function: Noun	Type B/S	Cost allocation: Basis	Cost allocation: Cost
Embedded board	3540	Lock	Object	B	Hole	3200
		Withstand	Force	S	Thickness	60
		Facilitate	Handling	S	Shape	80
		Ease	Assembly	S	Shape	40
Dc solenoid	1200	Facilitate	Handling	B	Shape	160
		Withstand	Force	S	Dia	900
		Position	Object	S	Length	250
		Ease	Assembly	S	Head	50

Table 4: Consolidated feature function matrix functions

Function	Components: Embedded board	DCS	Brake handle	Brake caliper	Brake pad	Electric circuit Assy
Lock object	Δ					Δ
Ensure Safety		Δ				Δ
Facilitate handling	Δ	Δ			Δ	Δ
Facilitate rotation			Δ	Δ		
Increase area						

Table 4: Continue

	Components					
Function	Embedded board	DCS	Brake handle	Brake caliper	Brake pad	Electric circuit Assy
Hold object						
Maintain gap		Δ				
Connect object			Δ	Δ	Δ	
Adjust length					Δ	
Ease assembly	Δ					Δ
Withstand force	Δ	Δ	Δ	Δ	Δ	Δ
Position object		Δ	Δ	Δ	Δ	Δ
Receive torque					Δ	
Sustain environment	Δ	Δ	Δ	Δ	Δ	Δ

Table 5: Parameter evaluation

Parameter	Key letter	Max. points	Min points for the acceptance	Balance points
Performance	A	100	80	20
Ease of operation	B	100	60	40
Ease of manufacture	C	100	50	50
Control and monitor	D	100	80	20
Ease of maintenance	E	100	50	50

Table 6: Product cost savings

Concept name	Product cost (Rs)	Savings w.r.to existing
Existing	18.500	-
Embedded controller	12.500	~ 6000
Embedded controller with IoT(implement all the area)	9.540	~ 2960

CONCLUSION

From the experimental and analyze the results the following conclusion can be drawn. The hydraulic brake control system developed in this research worked well during the functional analysis test using the test bed in the laboratory. When initial rotational speed of the brake disc is 600 rpm it can be stopped in 1.2 sec. In future IoT based monitoring improves efficiency of operation and reduced cost value.

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