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Stand Alone Compressed Air Energy Storage in Wind Turbine System

P. Ramanathan

Department of Electrical and Electronics Engineering,
Bharath University, Chennai, Tamilnadu, India

Abstract: The paper presents a new approach and new design of Wind Turbine System with steady electric output using Air Battery, air motor and generator regardless the rotating speed of the rotor. More particularly the system delivers constant voltage and constant frequency with controllable and presetable parameters. The major modules of the system incroporates, a wind powered rotor, Air Pump to charge Air Battery, Air Battery through pneumatic controller to Air Motor supplying air, Electric Generator driven by Air Motor, Control Components and interface controllers to deliver the power to utility grid or for use as standalone power station. In addition, by deriving energy completely from farm sources, this type of system may reduce some opposition to long distance transmission lines in rural areas, which may be an obstacle to large-scale wind deployment.

Key words: Wind turbine system · Pneumatic controller · Storage system · Air battery

INTRODUCTION

Wind energy systems that combine wind turbine generation with energy storage and long distance transmission may overcome these obstacles and provide a source of power that is functionally equivalent to a conventional baseload electric power plant. A 'baseload wind' system can produce a stable, reliable output that can replace a conventional fossil or nuclear baseload plant, instead of merely supplementing its output. This type of system could provide a large fraction of a region's electricity demand, far beyond the 10-20% often suggested as an economic upper limit for conventional wind generation deployed without storage [1-4].

A Technology Available for Scheduling: A system manager has to continuously monitor both the supplies and loads.

- While supplies could be controlled to some extent, loads can only be
- Anticipated and corrective measures taken.
- In this dynamic situation it is important to note that it is a balancing act with or without wind/solar power on the grid.
- With wind having its variability, the management would have to be only slightly more innovative.
- There are emerging technologies to forecast in short term (horizon of 60 hours).
- Validation and implementation is some distance away.

B Impact on Grid and Associated Equipment:

- After the area and capacity of a given wind farm are decided, Wind farm design preceded by detailed load flow analysis, impacts of voltage and frequency excursions, harmonics, seamless power factor controls and optimised.
- There are wind turbines which have facility to provide leading pfs if required.
- Wind farm Substations are built to meet strict standards laid down by the TRANSCos.

Need for Wind Power Storage: Three contexts:

- Make wind dispatch able (price arbitrage; potential at small market share)
- Boost wind capacity factor at large market penetration (offsets fuel cost only)
- Exploit high-quality but remote wind resources (by reducing transmission costs).

Corresponding Author: P. Ramanathan, Department of Electrical and Electronics Engineering, Bharath University, Chennai, Tamilnadu, India.

Compressed Air Wind Energy Storage: Certainly, two of the hurdles to relying on wind power for producing energy are the intermittent nature of the wind itself and the fluctuating prices producers get for feeding the resulting power into the grid.

One minute the wind is blowing (at a high enough rate to make power) and the next it isn't. Worse, sometimes when the wind is blowing, power is selling for the lowest possible price and when the turbines are still, power is worth the most. It's enough to make a wind farmer or utility pull its hair out.

While wind power generation may be the fastest growing segment of the renewable energy business and the raw materials used to make energy are ostensibly free, the whole business is a virtual Garden of Eden: paradise, but with some flaws.

Building wind farms is expensive and relying on them to generate either a sufficiently steady source of power for the world-or revenue for the operator-is a sketchy affair. But work is done to counteract these two negative pressures on the industry. Systems for storing wind energy created when the going is good and releasing it for use when the turbines aren't humming are being worked on now. But to date, industry sources say that there is not one operating wind farm in the world with this ability, although energy storage systems have been in use in other branches of the energy generation business since 1978 [6-10].

Standard Stand Alone Wind System: The basic components of a base load wind system include a large amount of wind generation, a large-scale energy storage system and long distance transmission. These previous studies assume that the wind/CAES system acts as a 'base load' plant with nearly constant output. Actual power plant operation, however, will likely use the energy storage system to reduce low-value output during off-peak periods and increase high-value output during on-peak periods, improving the economics of the system.

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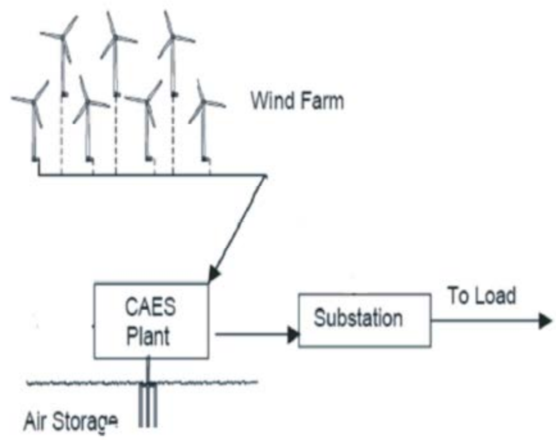


A base load wind system must incorporate a large-scale energy storage system capable of quickly responding to the variations of wind turbine generation. Compressed air energy storage (CAES) is a hybrid generation/storage technology well suited for this application. Energy is stored by compressing air in an airtight underground storage cavern. To extract the stored energy, compressed air is drawn from the storage vessel which rotates the air motor which in turn rotates the generator.

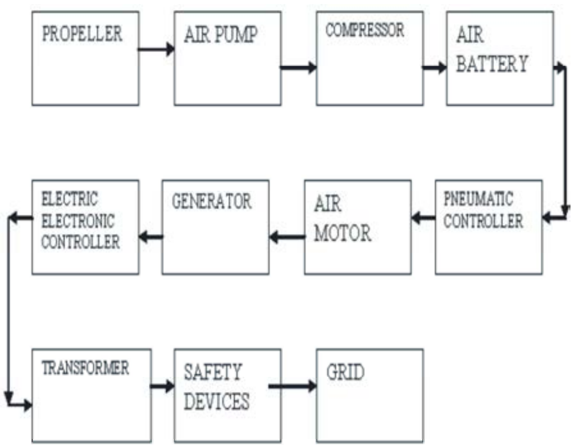
A large-scale CAES system requires an underground storage cavern in a salt dome, aquifer, or other geologic formation. Both existing CAES facilities use solution-mined salt caverns. Typical CAES systems operate with an air storage pressure range of 50-80 bar and require 200-300 m^3 per effective stored MW h. Leak rates in both hard rock formations and salt domes have been evaluated and found to be negligible. This study assumes that leak rates in aquifers would also be small enough to have minimal impact on technical or economic performance.

As part of a baseload wind system, CAES would be used to enable a nearly constant output by smoothing the highly variable output from wind turbine generation. The combination of roughly 1.5-3 MW of wind turbine generation operating at a capacity factor of 30-45% and 1

MW of CAES generation could produce a nearly constant 1 MW output. When operating at a high capacity factor (O75%), about 60-80% of the wind energy is placed directly onto the grid, while the remainder is stored (to be retrieved when the wind energy output falls below average) or 'spilled' (due to limits of the storage cavern and transmission capacity). A simplified schematic of a baseload wind system is illustrated.

The high capacity factor of a baseload wind system will fully utilize expensive transmission capacity, which is essential if long, high capacity transmission systems are to link inexpensive wind resources with major load centers.

BLOCK DIAGRAM

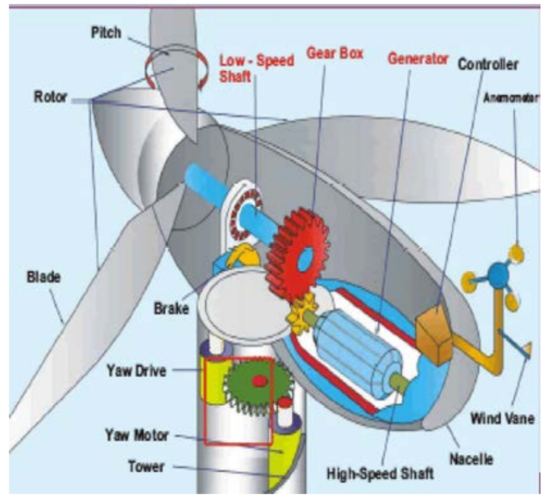


Wind Turbine System: (We assume we are familiar with operation of wind turbine)

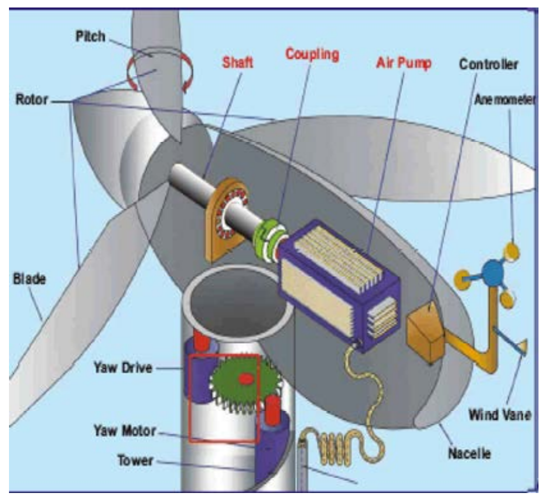
Technology	Capacity ($/kW)	Storage ($/kWh)
Compressed Air Energy Storage (CAES) (350 MW)	350	1
Pumped hydroelectric		
Advanced battery (10 MW)	120	10
Flywheel (100 MW)	150	300
Superconductor (100 MW)	120	300

Elements of Proposed System

Propeller: A ropeller is a type of fan which transmits power by converting rotational motion into thrust. It can be used to drive with a pump. It consists of one or more blades about a central shaft and operates like a rotating screw or wing. A pressure difference between the forward and rear surfaces of the airfoil-shaped blade is produced and air or water accelerated behind the blade. Propeller dynamics can be modeled by both Bernoulli's principle and Newton's third law.

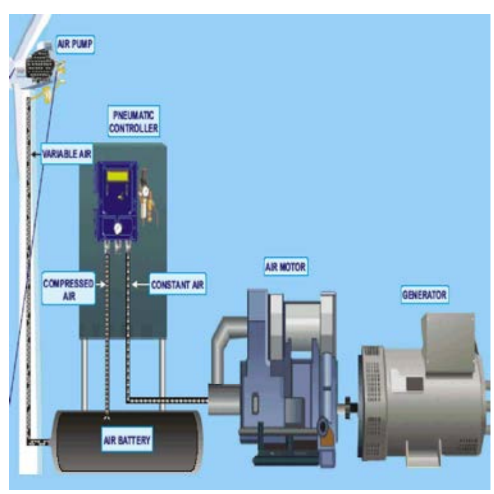


a) Normally used



b) Proposed

Fig. 1: Diagram showing a single proposed model of wind turbine:



Air Pump: A pump for condensing and forcing air through an aperture or pipe.

Underground Storage System (Air Battery): CAES plants use air pump to compress air into a storage system. When electricity is needed, the high-pressure air is withdrawn to run the generator as predetermined speed as required using pneumatic controllers. CAES may utilize an underground air storage reservoir or an above ground air storage system. Plants are designed requirements for plant size, in terms of MW capacity and in the number of storage discharge hours needed.

The goal for underground air storage systems is to verify the proper air flow rate and integrity metrics for the geologic formation used to store the high pressure air. Underground air storage systems are particularly cost-effective for bulk energy.

Selection of Storage System: FROM THE ABOVE TABLE CAES is clear choice for several hours (or more) of storage with Large capacity (> ~100 MW).

Storage when the discharge time interval is three to 12 hours. For above ground air storage systems, the project intends to determine the thermal and cyclic fatigue characteristics of the vessels or pipeline air storage system.

CAES can help integrate higher penetration of Wind and other renewable resources and enable increased grid stability. CAES plants can help reduce minimum loading issues of base load coal and nuclear plants. The major expected benefits from CAES plants will accrue from the following applications:

- Load Leveling
- Ramping
- Frequency Regulation

Pneumatic Controller: The device controls a maximum of 20 filter pulse valves and replaces the solenoid control unit. The pulse valves are connected to the pressure chamber of the controller by small bore airlines. The wiper arm assembly of the controller is operated by a pneumatic ratchet drive. It pauses between valve connections for a preset time which is adjustable by the user. The switching time is also user adjustable by means of a throttle valve accessed after removal of the bottom casing. During the switching time the wiper arm passes beneath a valve connection port and vents the pilot line to that particular valve. The valve opens and remains open until the wiper arm moves on to the next position. The pilot air is vented through the port marked „R“underneath the manual override knob, which is marked to show the exact position of the wiper arm. The control section consists of a pneumatic timer for adjusting the interval, throttle valve for adjusting the switching time and pneumatic ratchet drive for the wiper arm assembly.

The operating section consists of pressure chamber, control ports and wiper arm.

Fluid (Control Section): filtered air-compressed air supply via conditioning unit with a 5 to 10 ìm filter, without oiler (for unpurified compressed air).

Air Motor: A motor that is powered by a supply of compressed air instead of electricity or fuel combustion. Normally used in hazardous environments where sparks and flames are not permitted.

Generator: An electric generator is a device that converts mechanical energy to electrical energy, generally using electromagnetic induction. The reverse conversion of electrical energy into mechanical energy is done by a motor.

Working: A wind turbine comprising a propeller and an orthogonal coupling assembly drives a shaft connected to a air pump. The air from it is first connected to the output is protected by a check valve and leads into a pipe connected to a tank inlet pipe. The inlet pipe feeds into a holding tank capable of holding compressed air under a maximum pressure.

A pressure limit switch assembly senses the pressure in the holding tank through a pipe. A high pressure switch within the assembly is activated when the holding tank reaches the maximum safely allowable pressure. This switch through line causes the disengagement of the clutch. A second switch within the assembly is activated when the holding pressure falls below a preset limit.

Storage System: The system may comprise a pipeline that conveys the compressed air to a desired destination. These pipelines may be constructed according to guidelines similar to those used in the construction of natural gas pipelines. Larger pipelines may cost more to install, but may be capable of storing greater quantities of compressed air, such that the additional cost may be justifiable. Larger pipelines may also be capable of conveying compressed air at lower flow rates with lower frictional losses. Aspects of the invention, however, are not limited to any particular type of storage device, such as gas pipelines, as other devices may also be used to store compressed air.

Natural or man-made vessels may also be used as storage devices for compressed air. According to some embodiments, geographic features, such as salt-domes or exhausted natural gas cavities may be used to store compressed air. Similarly, man-made devices, such as pressure vessels, bladders and underground or underwater facilities may be used as the sole storage device for a particular system, or may augment the amount of storage provided by the pipelines of a particular system.

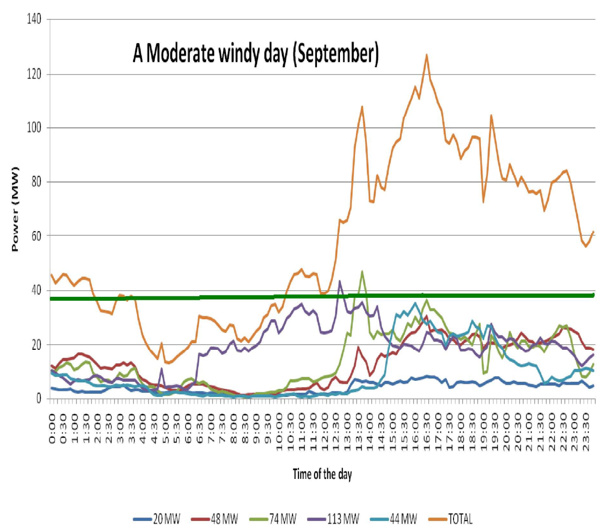
Embodiments of the system may store compressed air at various different operating Pressures. Generally speaking, systems that can store higher pressures may be more costly to produce, but can allow greater amounts of energy to be stored in a given volume of space. According to some embodiments, such as those that utilize pipelines constructed along guidelines normally used for natural gas systems, compressed air is stored at pressures up to 100 atmospheres. According to other embodiments, maximum storage pressures may be lower than 100 atmospheres, although maximum system pressures are generally greater than 10 atmospheres-a pressure that is higher than that normally associated with "shop air" systems. Still, other embodiments may store compressed air at pressures much greater than 100 atmospheres, as aspects of the invention are not limited in this respect.

By way of example, systems may be capable of achieving maximum storage pressures of 240 atmospheres are greater. Recently developed composite reinforced pipes may facilitate achieving these pressures.

Controls: The turbine is powered by the expansion of the compressed air supplied by the turbine feed tank. The turbine is similar to the compressed air motors used in certain impactors and drills. The turbine drives an AC generator designed to supply. The turbine is turned on by means of the valve controlled by an/off switch. When the pressure in the turbine feed tank reaches the high limit, the valve is closed. The high and low limit of sensors is not fixed but subject to minor variations in response to the speed of the turbine. The speed of the turbine and of the generator is monitored by speed sensor. The output of the speed sensor is inversely proportional to the speed of the turbine. The speed sensor signal is fed to sensor. If the output frequency of the generator deviates from the required. If the speed of the generator is slowed down by an increase in the load current, the high and low limits of sensor are raised in order to raise the pressure in turbine feed tank. The turbine will respond to the pressure change by increasing its rotational speed. The output of the generator is made available for use through lines and controlled by a switch.

Advantages of the New Technology: This power plant will accumulate air energy during the periods when the wind is blowing. The energy is stored in the form of compressed air in the holding tank. storage media are ecologically clean. Furthermore, the electrical system can boost the power of the compressed air system during periods of heavy power drain or long use.

The various mechanical and electro-mechanical components of the power plant such as the centrifugal clutch, compressors, generators, turbines, valves and pressure-activated switches are well known to those skilled in the art.



- PLF-upto 50percent (7to18 for normal plant).no cutoff required, due to steady depatches power all the time.hence higher PLF.
- No phase difference hence casding of any no of units possible.
- Clean predictable quality power output
- Isolated from wind power induced frequencies
- Does not need an input power from power grid for starting
- Can funstion as standalone station
- Does not need an reactive power
- No statr stop cycle
- Power output independent of input.hense no grid failure
- Power out steady
- No fluctuatoins in power

CONCLUSION

Studies have demonstrated that a baseload wind system based on wind generation and CAES is an economically viable method of generating electricity, particularly when considering carbon emission constraints. A baseload wind system using compressed air storage does not require combustion of natural gas fuel which increases the environmental and social compatibility of the system.

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