Storing Solar Energy in the form of Compressed Air Energy and Release to generate Electricity

Pushpendra kumar, Rahul Meena, Rahul Saini,
[a]B.Tech Research Scholars, Mechanical Engineering, Poornima Group of Institutions
[b]Assistant Professor, Mechanical Engineering, Poornima Group of Institutions
2016pgimerahul060@poornima.org
2016pgimerahul061@poornima.org
rajpoot.rath@gmail.com

Abstract

In today's scenario of renewable energy, we expects to store electrical energy for blackout (Non solar) hours of the day. Storage in forms of Battery which are used have limited cycles and huge maintenance cost. It is said that the most common solution for small to medium storage is batteries, although very good at accumulating energy they are very hard to recycle and are very dangerous if not used correctly. Yet the benefits of compressed air over electric storage are the longer lifetime of pressure vessels and materials are entirely nonthreatening as well as life time costs are possibly lower. Hence, it is thought to store the solar energy in form of compressed air and then further use the compressed air for generation of electrical energy. SCAES is a technique to stock energy generated at one period for use at the time of requirement. At convenient measure energy generated during phases of small energy demand can be free to meet higher demand phases.

Keywords: SCAES, flooded lead acid, Li-ion, Compressed air.

1. Introduction

The storage of energy is emerging as a greener way to support our existing electricity networks and improve the stability of our grids, as we step forward into a cleaner future and becomes more dependent on intermittent renewable generation sources [1]. At this time it becomes essential for us to stock the electricity, so it might be used when there is a peak in demand. Storing electricity in batteries is one of the most adopted way to do so. But now it's been a deep concern for us that these batteries are harmful as well as very hard to recycle. So to investigate the feasibility of using a Small scale Compressed Air Energy Systems (SCAES) in a domestic household application i.e. to offset the peak demand air conditioning places on local distribution networks and household economies.

To understand the SCAES technology and to differentiate it to existing energy storage technologies it is necessary to look at the requirement from an ideal energy storage system and then do a valuation on the existing technology. Equipment specifications for the components of the planned SCAES design were used to develop a theoretical model of the system. The results were then equated against a practical model using off the shelf items. The SCAES system for this paper is proposed to be entirely renewable (Figure 1,2) and can be split into two separate disciplines mechanical & electrical. Where by the electrical subsystem consists of PV cells, converter, air motor, turbine, generator and the mechanical (pneumatic) subsystem incorporates air compressor, receiver and an air motor.

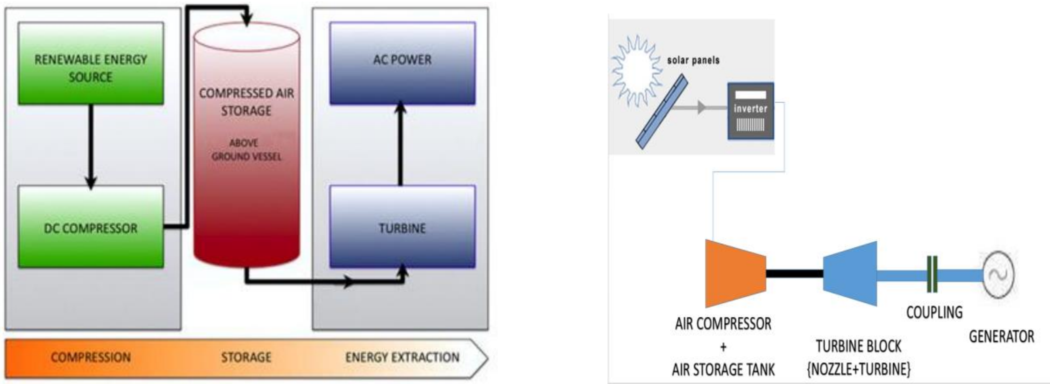

Figure 1, 2: Schematic of Renewable SCAES System

2. Literature Survey

1. Vadasz in 2009 proposed that the CAES technology comprises of converting additional base load energy into stored pneumatic energy in pressure vessels or secretive caverns with the help of a compressor for later discharge though a gas turbine as peaking power.

2. Primm in 2011 concluded during compression, heat is produced which is removed before it is stored. This heat energy can be accumulated in thermal energy storage for use at a later stage. In a power plant with a standard gas turbine, around two-thirds of the gas is used to compress the air. It therefore makes logic to use off-peak electrical power to pre-compress the air, and later use the compressed air in the gas turbines when the turbines are generating electricity during peak hours. By this, around three times the power is formed for the identical fuel consumption.

3. Analysis of Installed Energy Storage Technologies

In order to investigate the energy storage device it is important to first recognize the ideal features of such a storage system. In this research, work the emphasis was on addressing the energy storage necessities for a small renewable energy storage system. Preferred features of such an energy storage system could be a mixture of the following:

- High energy to weight ratio.
- High battery capacity.
- Quick recharge capacity.
- Long cycle life.
- Low cost.
- Robustness.
- Simple to maintain.
- Fast response.
- Greater Current fluctuation tolerance.
- Low self-discharge rate.
- Low effect of temperature.
- High voltage.
- High turn-around efficiency.
- High depth of discharge.
- Low environmental impact.
- High safety factor.

4. Efficiency of Conversion

"Efficiency" in energy storage systems most often refers to how well the system uses space or weight to store energy [2].

The efficiency of an energy device is a measureable appearance of stability between energy supplied and energy gained and can be defined as follows:

$$\text{DEVICE EFFICIENCY} = \frac{\text{USEFUL ENERGY OUTPUT}}{\text{ENERGY INPUT}}$$

With the alteration from one type of energy to another the transformation efficiency is never 100% and the output energy is constantly going to be lower than what is inputted which is evident from the equation above.

5. Selected Equipment for Design

Model of SCAES is fabricated (design) by using shelf equipment to accumulate

Compressed air to use as an energy basis. Preferably the system would have a small impression which is easily adjustable to any residential house without it being a uncomfortable setup. If the layout is successful the system would be easy to assemble inexpensive and transferable.

5.1 Photovoltaic Cells

Solar energy is the uncontaminated and greenest source of renewable energy which produces electricity. By adopting optimized cell technology the panel efficiency is said to be 15%. A benefit of adopting solar panels and a clean regulated supply is once fed to receivers according to the capacity, any excess energy generated by the panels can be fed back into the grid reducing the electricity costs as well as saves money also.

5.2 Air Compressor Package

AC motors are normally 85–90% efficient or more, when transforming electricity into mechanical power. The size of the motor used during analysis was 1.5 KW and characteristically for every single 746W the motor is rated to the compressor can produce 4 cubic feet per minute at 700Kpa. The category of compressor used was a single-acting reciprocating compressor which was air-cooled analogous to that of Figure 3. These types of compressor are said to be less effective than other types [3]. The compressors output was 8.8 CFM and held 0.065m^3 of compacted air in the receiver.

Air pressure regulator

An air pressure regulator same as in Figure 4, was required for the air motor during testing period as there is always be a need of constant pressure regardless of the increment and decrement of line pressure to authenticate the maximum efficiency outline of the air tools.

5.3 Air motor

Pneumatic motor or compressed air engine is a category of motor which creates mechanical work by intensifying compressed air. Pneumatic motors usually operates at 620Kpa and transform the compressed air to mechanical work either by linear or rotary motion. Linear motion can derived from either a diaphragm or piston actuator, although rotary motion is provided by either a vane type air motor or piston air motor. Figure 5 & 6 shows the category of air drill which were used. It is mostly of rotary vane type as this is the most common air motors used in small scale industries.

5.4 AC Generator

Though it is not tested in this design, it is being proposed that electrical output was mandatory. For this a generator would be essential to output a voltage which could be used though an inverter. This might ensure that the power is clean, green and usable at all sought of output.

6. Model Flow Diagram

Figure 9 below displays a flow illustration of the equipment itemized in Section 5 and in which mean they are functioning together.

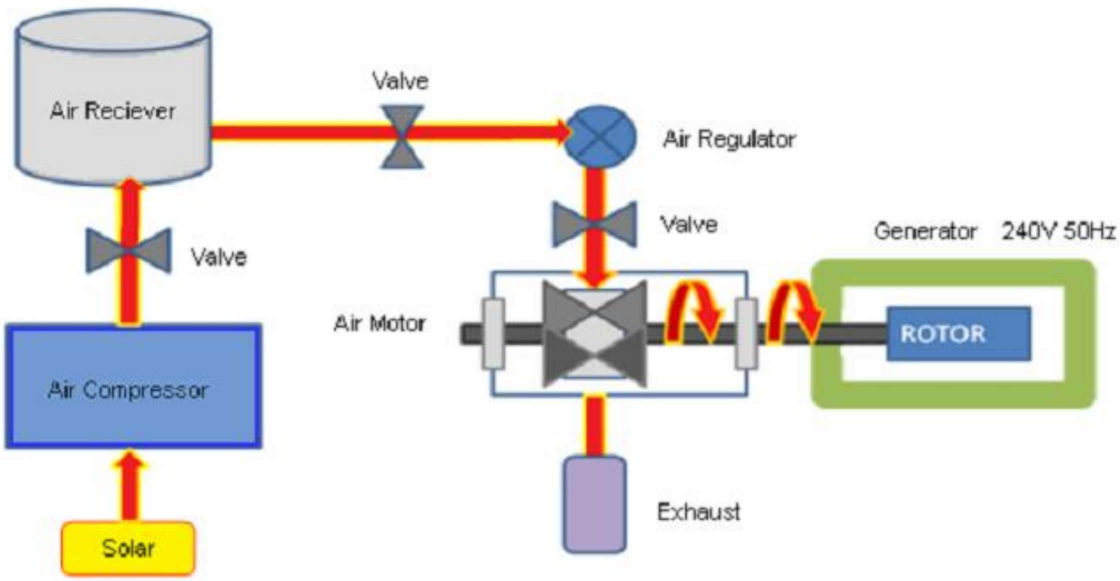

Figure 5: Flow Diagram (SCAES SYSTEM)

7. RESULTS FROM EXAMINATION OF PLANNED PROJECT

The total time which the compressor acquired to fill the $0.065m^3$ receiver was 120 seconds, which functioned out that the total energy which the compressor used was 53.5Whr. Perceiving the specification of straight drill, it can states that power output for the straight drill is 376w at 620Kpa, which if we relate to the angle dill air motor it comes out to be 365w at 650Kpa.
The overall efficiency of a compressed air system can be as low as 10 – 18 %.

8. CONCLUSION

The preliminary basis of this research was the theory that compressed air could offer a substitute to commercial energy storage technologies for domestic use.
The emphasis was on using off the shelf products that could be united in order to bring the required energy storage and delivery technique.
The complete efficiency of the SCAES system was very small and with advance research it would be unfold ways to increase efficiencies of SCAES by improving following important parameters:
Compression and decompression by using more effective isothermal processes.
Adding intermediate air receivers between pressures to increase the usable storage time and helping more effective heat transfer to take place.
Increasing the pressure above 1000 Kpa with larger compressor.
Replacing air tool with air motors designed for this application.
Recapturing the waste heat and using it in other areas.
Heating the air on output of receiver to add more energy back into the compressed air.

Acknowledgments

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