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Modeling of a Compressed Air Energy Electrification by Using Induction Generator Based on Field Oriented Control Principle

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Abstract – The objective of this paper is to propose a modelling of a small compressed air energy storage system, which drives an induction generator based on a field-oriented control (FOC) principle for a renewable power generation. The proposed system is a hybrid technology of energy storage and electrification, which is developed to use as a small scale of renewable energy power plant. The energy will be transferred from the renewable energy resource to the compressed air energy by reciprocating air compressor to be stored in a pressurized vessel. The energy storage system uses a small compressed air energy storage system, developed as a small unit and installed above ground to avoid site limitation as same as the conventional CAES does. Therefore, it is suitable to be placed at any location. The system is operated in low pressure not more than 15 bar, so, it easy to available component in country and inexpensive. The power generation uses a variable speed induction generator (IG). The relationship of pressure and air flow of the compressed air, which varies continuously during the discharge of compressed air to drive the generator, is considered as a control command. As a result, the generator generates power in wide speed range. Unlike the conventional CAES that used gas turbine, this system does not have any combustion units. Thus, the system does not burn fuel and exhaust pollution. This paper expresses the modelling, thermodynamic analysis simulation and experiment to obtain the characteristic and performance of a new concept of a small compressed air energy storage power plant, which can be helpful in system designing of renewable energy electrification. The system was tested under a range of expansion pressure ratios in order to determine its characteristics and performance. The efficiency of expansion air of 49.34% is calculated, while the efficiency of generator of 60.85% is examined. The overall efficiency of system of approximately 30% is also investigated.

Keywords: Compressed air energy storage, CAES, Induction generator, Field oriented control, FOC

1. Introduction

Nowadays, the energy consumption from fossil fuel combustion is one cause of global warming phenomena. Therefore, the use of efficient energy by avoiding combustion is considered. The alternatives for the power generation systems are renewable energy, such as, biomass, wave or tidal, water, wind and solar energy, which have great potential to generate electricity as they are abundant in nature, cost-effective and also cause a little harm to the nature. However, they are not the reliable energy source since the power cannot produce all the time. Thus, the more economical and efficient energy storage system is needed. There are many types of electricity storage, including (but not limited to) conventional batteries, flywheels, ultracapacitors, superconducting magnetic energy storage, flow batteries, pumped hydroelectric energy storage (PHEs), and compressed air energy storage (CAES). The CAES is therefore developed and proposed because of its long service period, low cost of energy, low cost of maintenance and operation and high power efficiency [1]. It has been demonstrated as one of the economical solutions for utility-scale energy storage on the hour timescale. The energy storage system application's range is shown in Fig. 1.

CAES has successfully implemented in Hantorf in Geramany, McIntosh in Alabama, Norton in Ohio, a municipality in Iowa, in Japan, and is now under construction in Israel [3]. The CAES generates power by storing the energy in terms of compressed air in the underground cavern.

The air is compressed during the off-peak periods, and is used on demand during the peak periods to generate power with a turbo-generator / gas turbine system. However, this system seems to be disadvantage as it is use quite large power facility and is needed for the large underground cavern, while having a limitation in terms of site installation. Therefore, it is considered not appropriate for using as a small renewable power generation in Thailand.

The CAES is applied on the hybrid energy storage system based on CAES and Super-capacitors energy storage with maximum efficiency point tracking (MEPT)

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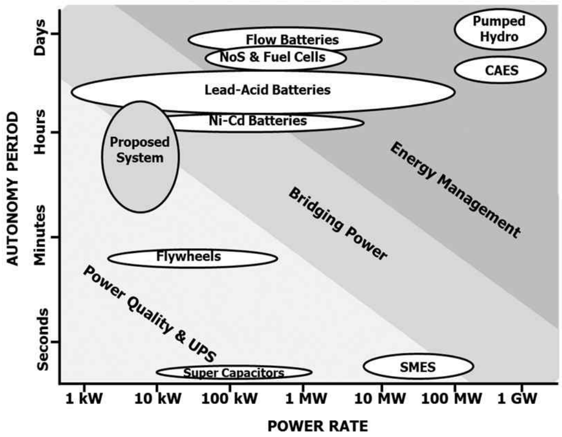


Fig. 1 Energy storage system application's range [2].

algorithm. It is implemented for the real time optimization of energy conversion by using power electronics converter. It improves flexibility and dynamic performances of the storage system and is suitable for a wide range of low power. The advantage over classical CAES plants includings site independence, fuel free operation and environmental harmlessness [4].

The transportable compressed air energy storage (T-CAES) system is applied from classical CAES. It discussed herein consists of 2.5 MW of wind turbine, the logic circuit for input power acceptance, a 500 kW electric motor, compressor, and turbo-expander/generator, storage tank and power conditioner. T-CAES system uses the ambient temperature compressed air and does not use combustion. The output of this system is electrical power and chilled air that obtain in expansion process. The draw back of this system works at high wind speed since the system needs the electrical power from wind turbine for driven compressor to produce the compressed air. Some 3-inch thick tanks can be used for storing the compressed air under high pressure but it is required special order for their production. The cost is also high [3]. Therefore, it is considered not appropriate for using as a small renewable power generation in Thailand.

In this paper, the small-compressed air energy storage system applies to wind power generation is proposed as shown in Fig. 2. The process of transfering wind energy to the S-CAES system starts with its driving air compressor engine at the ambient temperature to produce high-pressure compressed air which will be store in a ground tank, a temporary storage. When it is fully stored or on peak condition, the high pressure compressed air will be supplied to the air expansion unit, coupling with the shaft of induction generator to electric generation. On the other hand, the traditional CAES uses the gas turbine that complicates mechanics and costs expensively. Theoretically, the variable speed drives can produce 15% to 30% more energy output comparing with the constant speed [5]. The AC-to-DC Converter works for two modes operations, namely, rectifier and inverter. Rectifier mode is operated when

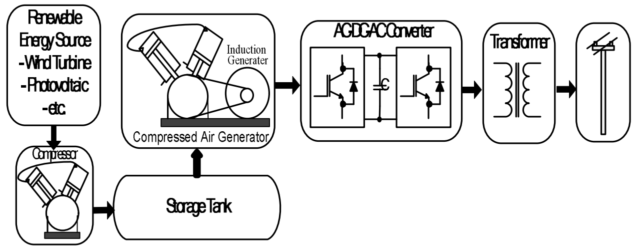


Fig. 2. A small compressed air energy storage system power plant.

the asynchronous machine is generator. It converts the alternating current (AC) to the direct current (DC). Inverter mode is operated as same as a static VAR to excite the magnetizing current. A grid connected converter is used to invert from DC to AC in order to connect to power lines and to control power quality. The main objective of this proposed system is to apply the CAES system, which is generally applied to the very large scale power system approximately MW-GW range, to be able to adopt with the power generation in a wide range of 1 kW to 10 kW shown as Fig. 1. That is, this proposed system is very flexible in terms of connecting the small scale in parallel connection.

This paper presents the modeling, thermodynamic analysis and simulation to obtain the characteristic and performance of a new concept of a small compressed air energy storage system power plant. The commands from CAES to control IG are determined. While driving the generator, pressure and flow of the compressed air change continuously during the discharge to drive the generator. Therefore, the system's response and performance of IG change when the input changes. The results can benefit system designing of renewable energy power plant. The paper is consisted of 4 sections: Introduction, Theory and Modelling, Simulation, Experimental Results and Conclusion. The proposed system is shown as Fig. 2.

2. Theory and Modeling

Basically, the concept of energy conversion process and air state changing of the CAES driven induction generator is described in Fig. 3. As the compressor, the electrical power converts into mechanical torque for sucking and compressing air from the atmosphere then the compressed air transmits the power from air to drive the prime mover coupling with generator, which the mechanical power converts back to electric power. The compressed air is

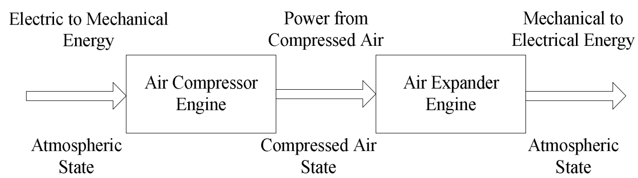


Fig. 3 Energy flow and air state in small CAES [6].

released back into the atmosphere that is the cooled air. It can also be utilize in other works.

2.1 Modelling of wind power conversion

The power from wind, (P_w) is the flux of kinetic energy, which the air interacting with rotor per unit time has a cross sectional area of rotor, A, can be written as

$$P_w = \frac{1}{2}\rho V_w^3 A \quad (1)$$

where ρ is the density of air, v is a volume of air portion available to the rotor and V_w is a wind speed. Typically, the air density may be taken as 1.225 kg/m^3. We can see that the factors influencing the power are air density, rotor area and wind velocity. Effect of wind velocity is more prominent owing to its cubic relationship with power. However, wind power cannot be fully converted to mechanical power, so the power at the shaft is

$$P_w = \frac{1}{2}C_p \rho V_w^3 A \quad (2)$$

where Cp is the wind power coefficient, dependent on the ratio between the turbine speed $\omega_T R$ and wind speed. This ratio, called tip speed ratio λ, is given as:

$$\lambda = \frac{\omega_T R}{V_w} \quad (3)$$

Where R is the radius of the turbine and ω_T is the turbine angular speed. Theoretically is $C_p \le 0.593$ (Betz limit). Thus, the maximum power that can be realized from a wind system is 59.3% of the total wind power [1]. Actual values will probably lie between 25% and 30%. This will vary with wind speed, with the type of turbine and with the nature of load [7]. The power in the wind is converted to mechanical power with an efficiency (coefficient of performance) C_p which is transmitted to the generator through a mechanical transmission with efficiency η_m and which is converted to electricity with an efficiency η_g. The electrical power output, (P_e) is then

$$P_e = \eta_m \eta_g P_w \quad (4)$$

Optimistic values for these coefficients are C_p = 0.45, $\eta_m = 0.95$ and $\eta_g = 0.9$ which give an overall efficiency of 38% [8].

2.2 Thermodynamics of compressed air energy conversion

Power of air can be produced by compressing air at atmosphere and storing it under pressure, and then used in the working process by air expander or turbine. In compressed air production, the least amount of work, which is required in air compression, is considering as polytropic process. Air is assumed to perfect gas which specific heat is constant. Use an ideal gas, which relates temperature (T), pressure (P) and volume (V) of gas as shown by $PV = nRT$, where n is the number of mole and R is the gas constant. The work for producing the compressed air as polytropic process is shown as

$$W = \frac{\gamma}{\gamma-1} * P_1 V_1 \left[\left(\frac{P_2}{P_1} \right)^{\frac{\gamma-1}{\gamma}} - 1 \right] \quad (5)$$

Where P_1, P_2 and V_1, V_2 are the pressure and volume of the initial state and the final state that are atmospheric state and compressed air state, respectively. In expansion process, the work potential of compressed air expansion can calculate as the same Eq. (5) but the air state change is opposite that is compressed air state change to atmospheric state (show in Fig. 3). Therefore, in during compressed air discharge to drive the reciprocating machine that the shaft couple with shaft of generator, the air pressure in vessel will decrease. As the result, the speed of generator will change following as condition leading to electric power generation is change. The power is work per unit time and air flow (Q) is volume per unit time ($Q=V/t$), so the compression power, (P_c) is

$$P_c = \frac{\gamma}{\gamma-1} * P_1 Q \left[\left(\frac{P_2}{P_1} \right)^{\frac{\gamma-1}{\gamma}} - 1 \right] \quad (6)$$

Where γ is the ratio of specific heat, $\gamma = c_p / c_v$, (P_2/P_1) is the compression ratio. The power is directly depend on pressure and air flow, therefore, in during compressed air discharge to drive the air expander coupling with shaft of generator, the speed of generator will change follow as conditions resulting to the power generation is change.

2.3 Wind energy driven compressed air energy storage system

Applying wind power Eq. (2), electric power Eq. (4) and the compressed air power Eq. (6), the compressed air flow driven by wind energy can be expressed by

$$Q = \frac{0.5 * c_p \eta_m \eta_g \rho V_w^3 A}{(\gamma/\gamma-1) * P_1 \left[(P_2/P_1)^{\frac{\gamma-1}{\gamma}} - 1 \right]} \quad (7)$$

We can see that power is directly depend on pressure and air flow, which vary with wind speed. On the other hand, the work potential of compressed air can calculate as the same Eqs. (5) and (6) but the air state change is opposite that is compressed air state change to atmospheric state (show in Fig. 3). Applied Eqs. (2) and (6), the energy efficiency of expansion power to wind power, η , is:

$$\eta = \frac{P_c}{P_w} = \frac{(\gamma/\gamma-1)*P_1 Q_1\left[\left(P_2/P_1\right)^{\frac{\gamma-1}{\gamma}}-1\right]*\eta_s}{0.5*C_p \rho V_w^3 A} \tag{8}$$

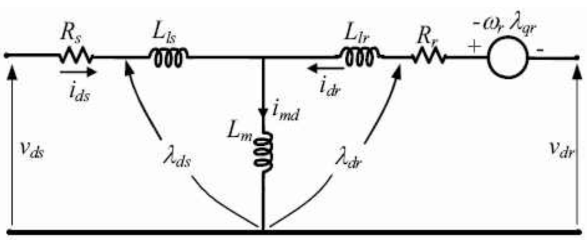
Where $\eta, \eta s$ is the efficiency of compressor and compressed air generator, respectively. Moreover, the both powers must multiply with time of compression until full store and time of expansion until empty tank to be same unit of powers.

2.4 dq induction machine model

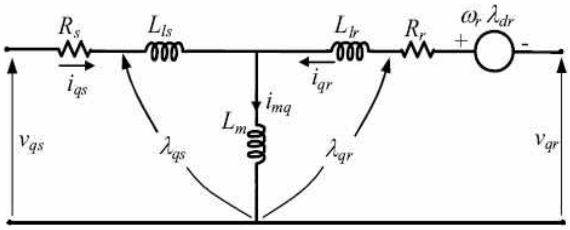
The induction machine can be modelled in dq stationary reference frame circuits as shown in Fig. 4. The dq model is powerful for analyzing the transient and steady state conditions, which give complete dynamic solution. The matrix equations are given as following [5, 9]:

$$\begin{bmatrix} v_{qs} \\ v_{ds} \\ v_{qr} \\ v_{dr} \end{bmatrix} = \begin{bmatrix} R_s + pL_s & 0 & pL_m & 0 \\ 0 & R_s + pL_s & 0 & pL_m \\ pL_m & -\omega_r L_m & R_r + pL_r & -\omega_r L_r \\ \omega_r L_m & pL_m & \omega_r L_r & R_r + pL_r \end{bmatrix} \begin{bmatrix} i_{qs} \\ i_{ds} \\ i_{qr} \\ i_{dr} \end{bmatrix} \tag{9}$$

where R_s, R_r are stator and rotor resistance, L_{ls}, L_{lr} are stator and rotor inductance, L_m is mutual or magnetizing inductance, $\lambda_{ds}, \lambda_{qs}$ are dq magnetic flux of stator, λ_{dr}, λ_{qr} are dq magnetic flux of rotor, v_{ds}, v_{qs} are dqsatator voltage, v_{dr}, v_{qr} are dq rotor voltage, i_{ds}, i_{qs} are dqsatator current, i_{dr}, i_{qr} are dq rotor current, ω_r is rotor angular velocity.



(a) d-axis circuit



(b) q-axis circuit

Fig. 4. dq induction machine model in stationary reference frame

2.5 dq induction generator model

Generally, the induction generator requires the reactive power, which will supply the excitation current to the core and generate a rotating magnetic field, for build up the output voltage. However, the excitation current is provided from an external source such as battery, charged capacitor and grid utility. One application connects the charged capacitor across terminal stator and drives rotor shaft by external prime mover, the voltage at stator terminal will be build up. This process call "self excited induction generator". The matrix equations for dq model in stationary reference frame without load are shown as following.

$$\begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} R_s + pL_s + \frac{1}{pC} & 0 & pL_m & 0 \\ 0 & R_s + pL_s + \frac{1}{pC} & 0 & pL_m \\ pL_m & -\omega_r L_m & R_r + pL_r & -\omega_r L_r \\ \omega_r L_m & pL_m & \omega_r L_r & R_r + pL_r \end{bmatrix} \begin{bmatrix} i_{qs} \\ i_{ds} \\ i_{qr} \\ i_{dr} \end{bmatrix} \tag{10}$$

When it connects with load, R_L, (considered resistive load only), the output voltage (v_{ds}, v_{qs}) are following:

$$\frac{dv_{ds}}{dt} = \frac{i_{ds}}{C} - \frac{v_{ds}}{R_L C} \tag{11}$$

$$\frac{dv_{ds}}{dt} = \frac{i_{ds}}{C} - \frac{v_{ds}}{R_L C} \tag{12}$$

The general mechanical equation in generating mode is given as

$$\frac{dv_{ds}}{dt} = \frac{i_{ds}}{C} - \frac{v_{ds}}{R_L C} \tag{13}$$

Where T_e is electromagnetic torque and J is inertia. Finally, the mechanical power required to drive the induction generator is given by

$$P_m = T_m \omega_m \tag{14}$$

where, T_m is mechanical torque in shaft, ω_m is mechanical shaft speed. The whole equations are used to determine the algorithm of field oriented control, FOC, for induction generator.

2.6 Modeling of CAES integrated with IG

In field oriented control, the relationship of flux, (i_{ds}^{e*})

and torque, (i_{qs}^{e*}), producing current that are function of electromagnetic torque are determined as command to control. The (i_{ds}^{e*}) sets the machine flux level, which is defined constant so it able to produce full torque. Set (i_{ds}^{e*}) equals to magnetizing current, (i_m), which is determined by machine open circuit test. R_s is neglected because of $\omega L_m >> R_s$. Therefore,

$$i_{ds}^{e*} = \frac{V}{\omega_e * (L_{ls} + L_m)} \tag{15}$$

At steady state, the rotor flux linkage is constant that results to $\lambda_r = L_m i_{ds}^{e*}$, therefore, the relation of the electromagnetic torque and control current are shown as

$$T_e = \frac{3}{2}\frac{P}{2}\frac{L_m^2}{L_r} i_{ds}^{e*} i_{qs}^{e*} \tag{16}$$

Set the electromagnetic torque equal to mechanical torque and the mechanical power equals to the air expansion power, which is the prime mover of generator. Apply Eqs. (6), (14) and (16). Therefore, the torque current demand (i_{qs}^{e*}) is

$$i_{qs}^{e*} = \frac{\frac{\gamma}{\gamma - 1} * P_1 Q \left[\left(\frac{P_2}{P_1} \right)^{\frac{\gamma-1}{\gamma}} - 1 \right]}{\omega_m * \frac{3}{2}\frac{P}{2}\frac{L_m^2}{L_r} i_{ds}^{e}} \tag{17}$$

The current (i_{qs}^{e*}) and (i_{ds}^{e*}) relate with every equations, therefore, the both currents are command in control. The current (i_{ds}^{e*}) will control the machine flux linkage and the current (i_{qs}^{e*}) will control the machine torque and generated the reference slip frequency, (ω_{sl}) that correspond to the efficiency of drive system is shown as:

$$\omega_{sl} = \frac{R_r}{L_r} * \frac{i_{qs}^{e*}}{i_{ds}^{e*}} \tag{18}$$

The slip frequency is added to the instantaneous rotor speed, ω_r, in order to produce the angular frequency, (ω_e). Then, ω_e is integrated to give the flux angle, (θ_e) which is expressed as:

$$\theta_e = \int (\omega_{sl} + \omega_r) dt \tag{19}$$

Since, the control current (i_{qs}^{e*}) and (i_{ds}^{e*}) are expressed in synchronous rotating reference frame. They are considered same as dc quantities, they will be changed to ac quantities in stationary reference frame, which are expressed as:

$$\left.\begin{aligned} i_{as}^{s*} &= (i_{ds}^{e*}\sin\theta + i_{qs}^{e*}\cos\theta) \\ i_{bs}^{s*} &= \frac{\sqrt{3}}{2}(i_{ds}^{e*}\sin\theta + i_{qs}^{e*}\cos\theta) - \frac{1}{2}(i_{ds}^{e*}\cos\theta - i_{qs}^{e*}\sin\theta) \\ i_{cs}^{s*} &= -\frac{\sqrt{3}}{2}(i_{ds}^{e*}\sin\theta + i_{qs}^{e*}\cos\theta) - \frac{1}{2}(i_{ds}^{e*}\cos\theta - i_{qs}^{e*}\sin\theta) \end{aligned}\right\} \tag{20}$$

3. Simulation

The simulation consists of two sections. The first is to find the thermodynamic relation of wind power to air energy conversion process both compression and expansion. The second is to find the characteristic of induction generator, which is driven by the compressed air engine. Thermodynamic simulates under some conditions, 2 cylinders of compressor, temperature T=293 K., atmospheric pressure 1 atm and γ=1.3. Fig. 5 shows the compression work from compressor when change the pressure ratio. This is meaning that the compression work will increase following the pressure ratio. This compression work is the energy that must use for

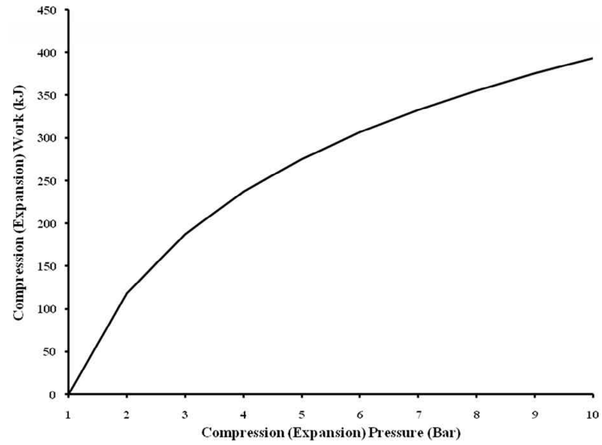


Fig. 5. Compression work under vary compression pressure conditions

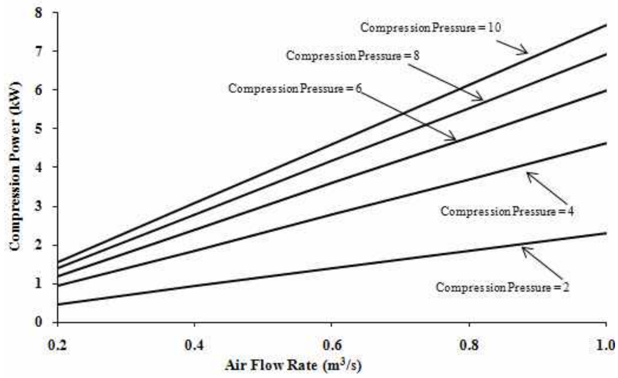


Fig. 6. Compression power under vary compression pressure and Air flow

producing compressed air. On the other hand, the expansion work has the same results but it different in the sign and air state change.

Fig. 6 expresses the power from compression process under conditions of pressure ratio and air flow change. The compression power, which is power consumption, directly depends on air flow rate and pressure ratio.

Fig. 7 shows that the air flow rate will increase when the wind speed increase and the pressure ratio decrease. This is meaning that the compressor capacity will increase follow increase of wind speed.

Fig. 8 express that the energy efficiency of the system under change of expansion pressure. Assuming 200 minute for time of compression until full store of 20,000 liter and 50 minute for time of expansion until empty tank at 0.4 m^3/min of air flow rate to drive generator, and 0.85 of η_s. As a result, we can see that the energy efficiency of the system is increase follow increase of pressure ratio. Therefore, we can improve the system efficiency by increase the stage of expansion. Although more stage can increase the efficiency, but the system is complexity and high initial.

The induction generator simulation is implemented by using MATLAB/SIMULINK to determine the behavior of the drives system that is shown in Fig. 9.

It consists of 2 simulations: constant supply voltage and frequency condition and open loop variable speed field oriented control. The simulation starts at compressed air engine, the power from expansion process under various air pressures at constant air flow, 1000 l/min and atmospheric pressure 1 atm, will determine. After that mechanical torque will be calculated. Both values are shown in Table 1. For the first simulation, the constant frequency of the supply terminal voltage of induction

Table 1. Expansion power and torque calculation

Expansion Pressure (MPa)	0.2	0.4	0.6	0.8	1.0
Power (kW)	1.16	2.31	2.99	3.45	3.84
Torque(Nm)	0.77	1.54	1.99	2.30	

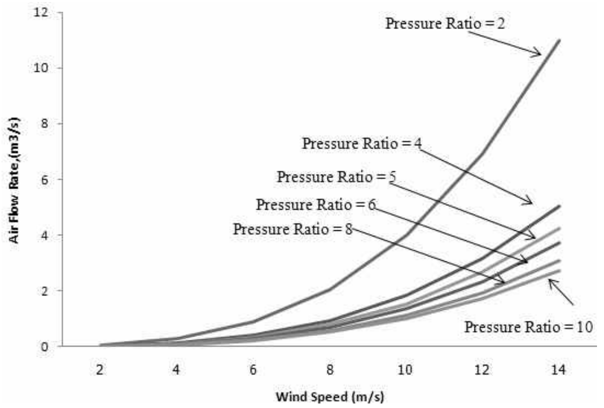


Fig. 7. Air flow under vary wind speed and pressure ratio conditions

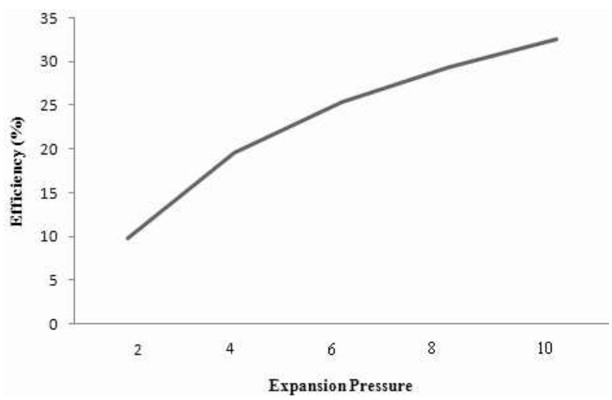


Fig. 8. Energy efficiency under change of expansion pressure and maintenance cost

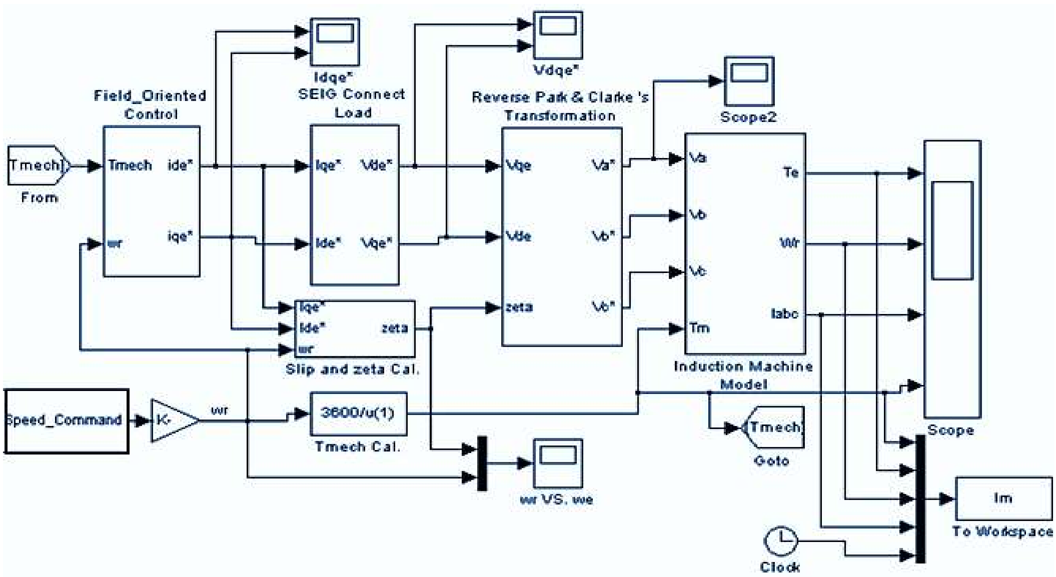


Fig. 9. MATLAB/SIMULINK Diagram of the variable speed field oriented control

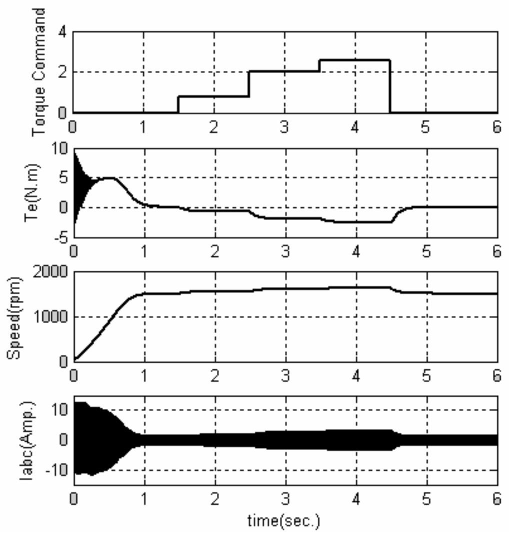


Fig. 10. Dynamic respond of induction generator under vary the mechanical torque from air expansion

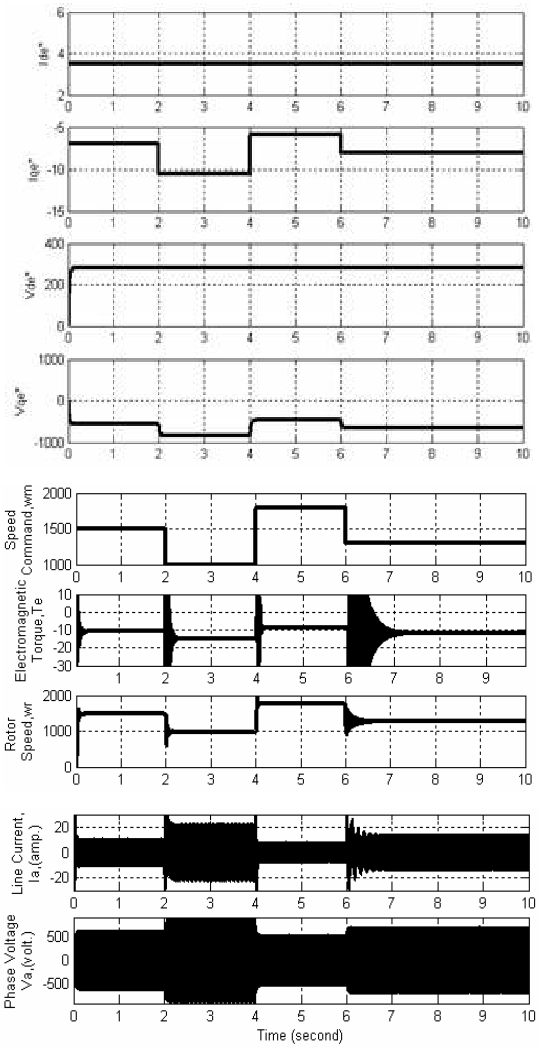


Fig. 11. Dynamic respond of induction generator when change the speed of prime-mover

machine is set at 50 Hz. The mechanical torque, 0.77, 1.99 and 2.56 N.m, from Table 1 are applied to the induction machine model at times 1.5, 2.5 and 3.5 second, respectively.

Fig. 10 shows the dynamic response of electromagnetic torque, (T_e), rotor speed, (ω_r), and line currents, (i_{abc}), which will be changed at mechanical torque command. It reaches to steady state at 1 second in which the induction machine is in motor mode. After that the mechanical torque is applied starting at 1.5 sec., the electromagnetic torque is negative in which the induction machine works in generator mode. Finally, the variable speed field oriented control is simulated by change the speed command and assume flux constant. This condition is simulated closely to the characteristic of the air pressure supplying from the tank changed. The simulation results show the response of voltage (v_{dq}), current (i_{dq}), line current (i_{abc}), phase voltage (v_a), rotor speed (ω_r) and the electromagnetic torque (T_e) that change follow speed command that shown in Fig. 11. We can see that the rotor speed, ω_r, line current, I_a, and phase voltage, v_a, change as ω_m change. These results mean that induction generator extracts the power from air expansion engine. i_{ds}^{e*} and v_{ds}^{e*} are constant because we assume flux constant. i_{qs}^{e*}, v_{qs}^{e*} and T_e are negative and change follow ω_m change. It means that the induction machine is working in generator mode.

4. Experiment and Result

This experiment diagram is shown in Fig. 12. It was done 11 times under change of operating pressure. Fig. 13 presents the power and speed will increase as operating pressure. This is means, when the speed of prime mover increases in order to the system produces the electrical power increase, too. The relation of speed, power and operating pressure will advantage in design of induction generator driven by compressed air system for alternative energy application.

Fig. 14 presents the relation of the power components in system and operating pressure change. The components of power considering in system compose of three segments. One is power of compressed air that is input energy enter

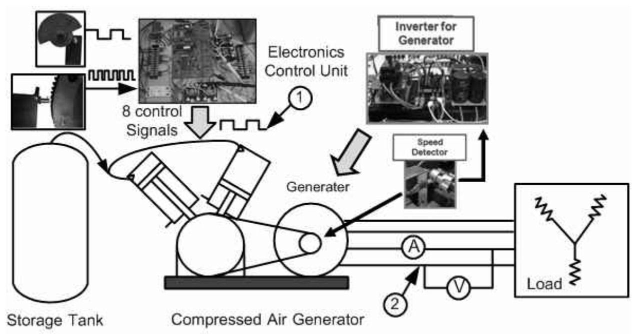


Fig. 12 Experiment configuration

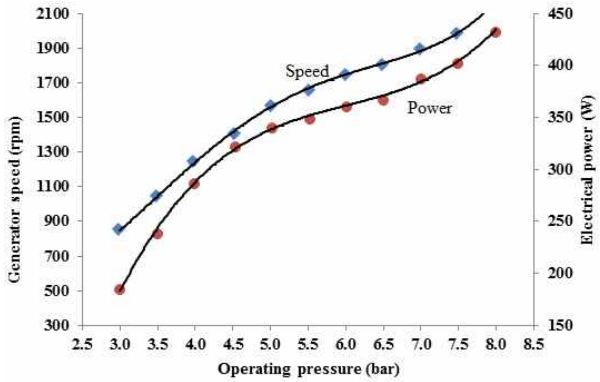


Fig. 13. Electrical power and speed relation of generator under operating pressure change

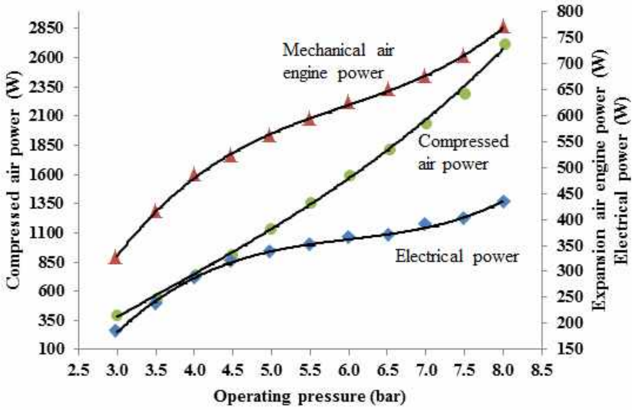


Fig. 14. Relation of the power components in system, efficiency and operating pressure

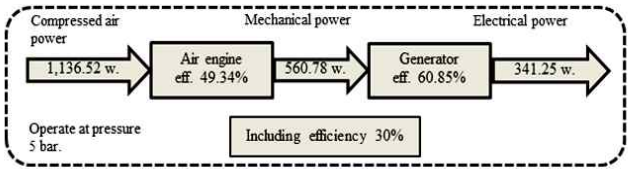


Fig. 15. Power transfer from compressed air power to electrical power

to drive the pistons of engine by using pressurize air. Second is mechanical power, which transfers from the compressed air power via expansion air engine. The last is electrical power that transfers from mechanical power via induction generator that is controlled by FOC principle. The total powers will increase when the input pressurize air increases. This relation shows an advantage when it comes to design the volume of the storage tank. The power transfer of the compressed power to electrical power indicates in Fig. 15 is a significant example. At the operational pressure of 5 bar, the engine turns 64.5 rpm with a torque of 83 N.m. Here, the compressed air power of 1,136.52 W is estimated. The mechanical power of 560.78 W is also calculated. In addition, the electrical power of 341.25 W is eventually estimated. Based on the power transfer shown in Fig. 15, the efficiency of expansion air engine (η_1), that is defined by electrical power output divided by compressed air power, of 49.34% is investigated, while the efficiency of generator (η_2) of 60.85% is examined. Here we can see that the overall efficiency of system is approximately 30%.

However, the engine will loss from three main causes when the engine operates in high pressure: one is thermo-dynamic loss resulting from difference of input-output air temperature. Second is loss from mechanic components. Finally is loss from leak of compressed air in the system especially the compressed air release out to the environment via the hole of lubricant oil on the body of engine because of leakage via piston ring. The engine operates at high pressure resulting to the compressed air high flow out, too.

5. Conclusion

This study is to propose the modelling of a small compressed air energy storage system which drives an induction generator based on a field-oriented control (FOC) principle for a renewable power generation by simulation and experiment to prove a new concept of the small compressed air electrification. The simulation results show that, the compression and expansion pressure depends directly on air flow rate and system efficiency. Therefore, to improve the system efficiency of thermodynamic conversion, the system should be able to operate under high pressure by increasing the stage of expansion, which the system is complex, high initial and expensive cost of maintenance. Then, an induction generator is simulated, it shows the dynamic response, which runs in motoring and generating modes. It can extract the compressed air power depending on the input speed conditions. Therefore, it can produce the power in wide speed range. The simulation results can be helpful in system designing for the renewable energy conversion system. Finally, an experiment is to investigate the characteristic of the induction generator, which is driven by compressed air under conditions of operating pressure change. The significant results showed that compressed air power of 1,136.52 W is estimated, while the mechanical power of 560.78 W is calculated. The electrical power of 341.25 W is also estimated. In addition, the efficiency of expansion air of 49.34% is calculated, while the efficiency of generator of 60.85% is examined. The overall efficiency of system of approximately 30% is also investigated.

The experiment has shown the relationship of the power component of the system and power consumption that can be used to design of induction generator driven by compressed air system for alternative energy application. The proposed system can apply to uninterruptible power supply, peak shaving for the energy building management, pneumatic application and air power vehicle (APV).

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