Electrically Varying Tension Power Generating (eVaT Gen) Exercise Bicycle

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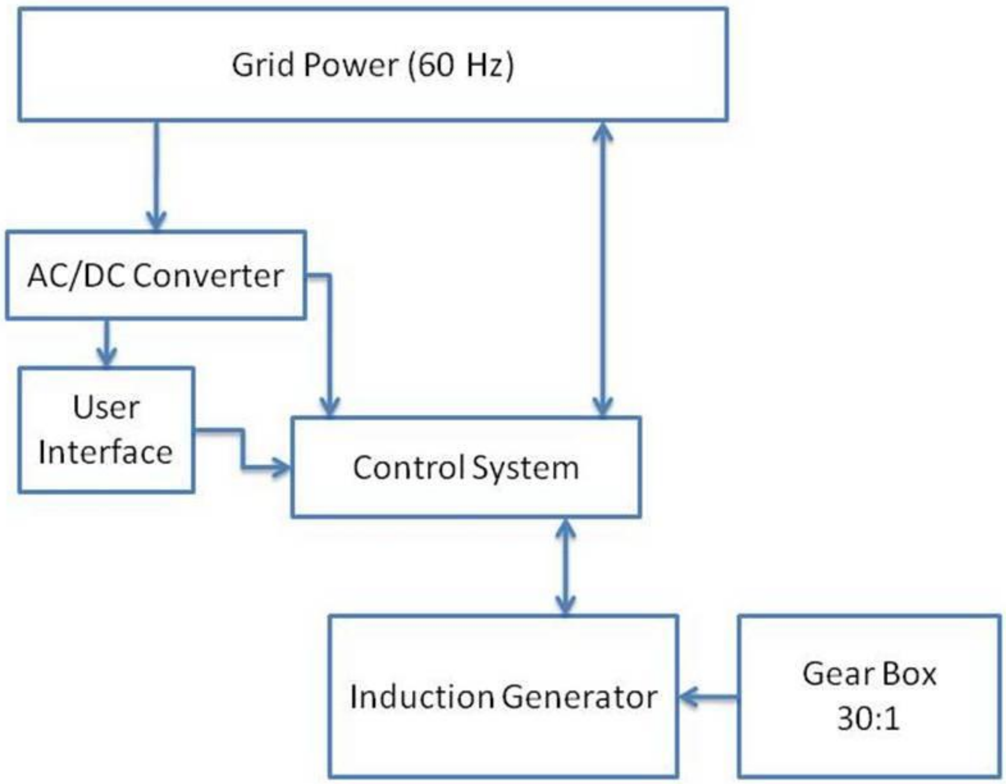
Motivation:
Every action human beings do, most often when we exercise, exerts energy. In an age when people are looking more and more for alternate sources of electric energy as well as new ways of saving money, an exercise bicycle that generates energy as you pedal would be an excellent solution for both problems. Being a common idea, the novelty of this project lies in removing mechanical controls and external resistances by simply controlling the electrical inputs to an Induction Generator.

Objective:
This project aims to design an exercise bicycle that generates electric power as a person pedals by using an induction generator. The resistance on the pedaling will be changed by controlling the voltage at the input of the induction machine, which can be indicated by +/- buttons on a simple panel by the handles. This would allow for more power to be produced with higher resistances. A control system would ramp up the voltage to indicated resistance value when the cycle is in use, and ramp it down to zero when use is discontinued. This will maintain proper generator functionality on the machine. A single gear ratio will take the lower speeds of pedaling and make them closer to synchronous speed, thus generating power. The control will take 60Hz power from the grid transform the voltage to desired level. The use of the induction machine allows for simple integration into the grid of the power generated.

Benefits:
- Save on electric bills: More fit, more exercise, more savings
- Reduced noise, compared to traditional exercise bikes

Features:
- Production of grid-ready electric power while pedaling
- Reduction of mechanical parts due to electric controls
- Simple controls
- Variable resistance internal to induction machine

Block Diagram:



Block Descriptions:

- 60 Hz Power
  - Output: 60 Hz power from the grid
- AC/DC converter
  - Takes 60 Hz AC power from the grid and converts it to 5V DC power used by the User Interface and controller (Control System).
- User Interface
  - Control Panel with buttons for user to press. These will indicate to a controller the level of resistance desired for the pedaling by sending a distinct signal for each button pressed.
- Control System
  - The control panel with '+' and '-' signals indicate to the microcontroller whether to increase voltage setting or decrease. It will also have a 10x1 led array indicating the voltage level at which the system is currently set ("LED Tension Level", see Fig 1). A warning LED will also light up when power generated is below 50W. A variac will control the peak to peak voltage given to the machine. This device, in turn, is controlled by a servo, which gets its PWM signal from the microcontroller.

- Gear Box
    - The Gear Box contains a gear ration of 30:1 to increase the rotational speed from the pedals. This will make a pedaling speed above 60 rpm be above synchronous speed (1800 rpm) at the Induction Machine Rotor.
- Induction Generator
    - When pedaling, its rotor will move above synchronous speed, thus generating electric power.

Schematics:

Fig 1. Schematic of Power Control

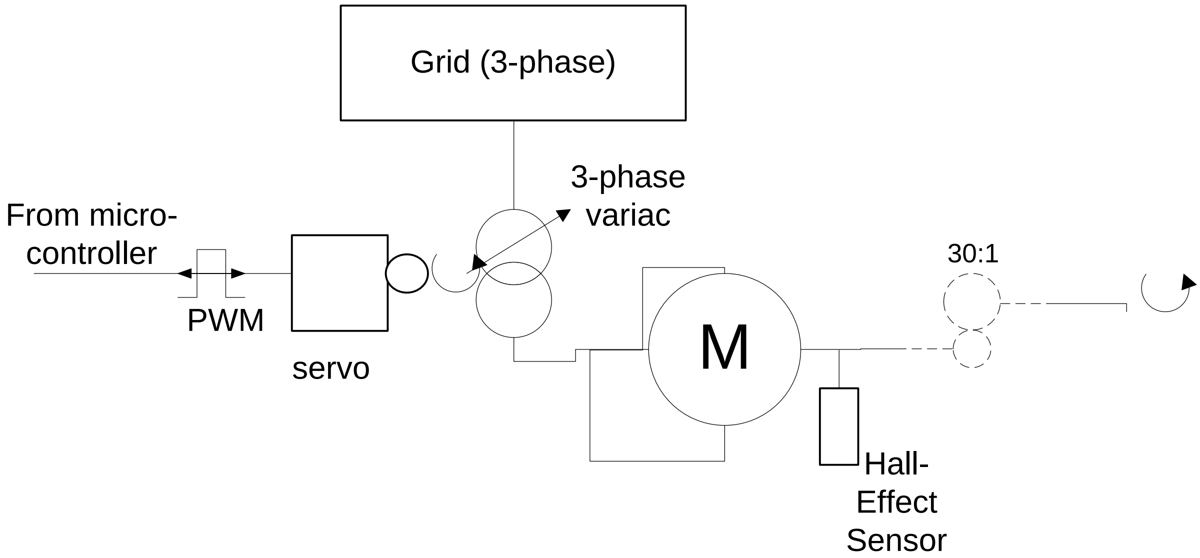


Fig 2. Control Panel Layout

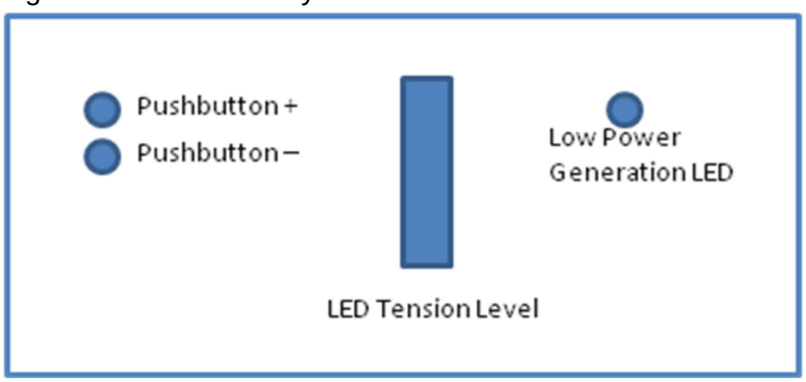
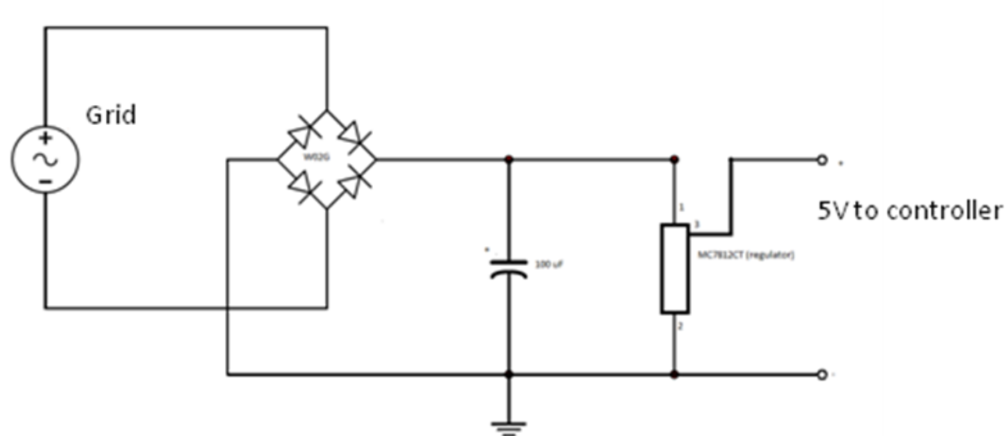
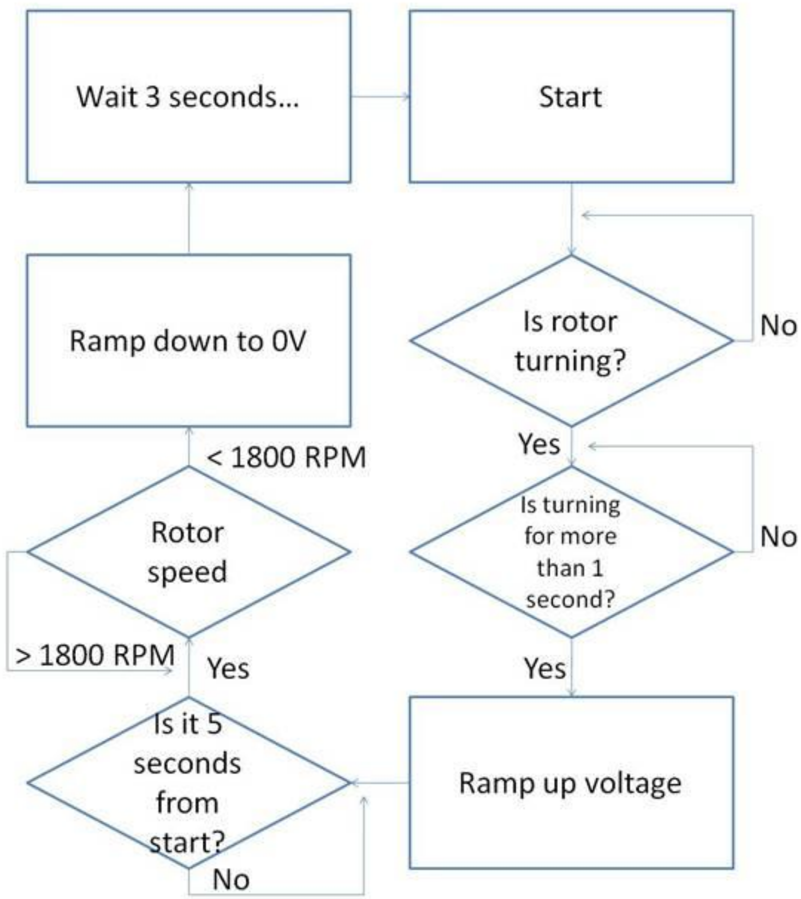


Fig 3. Rectifier to power microcontroller and other logic components



Flow Chart:



"Calculations":

Table 1. Taken from measurements performed for Lab 5 of ECE431 (Electric Machines) in spring 2009. Speed is the control variable being modified, while torque and power are being observed.

P1 (W)	P2 (W)	Ia (A)	Ic (A)	Vab (V)	Vcb (V)	Speed (RPM)	Torque (Nm)
93	166	2.22	2.22	74.9	75.1	3396	0.09
40	135	1.78	1.78	75.4	75.7	3446	0
46	100	1.33	1.33	75.9	76.1	3496	0
18	66	0.9	0.9	76.5	76.7	3546	0.215
-17	29	0.62	0.62	77.2	77.4	3596	0.555
-59	-6	0.84	0.87	77.8	78	3646	0.915
-103	-39	1.34	1.38	78.3	78.6	3696	1.3
-150	-70	1.92	1.96	78.9	79	3746	1.675
-200	-101	2.52	2.56	79.2	79.4	3796	2.045

Requirements & Verification:

1. Grid power must provide 3-phase power, each phase 120 degrees out of phase with each other.	1. Step down the grid voltage from 230V to 12V AC. Connect oscilloscope to two phases at a time and measure phase difference. Confirm each pair of phases is 120 degrees out of phase.
2. AC/DC converter must output a constant 5VDC. a. Diode rectifier must make all input voltages positive b. Capacitor must make signal fluctuate less than 1V. c. Regulator output must yield a constant 5VDC.	2. Connect one phase from the grid to the converter. Confirm 5VDC at output by measuring with an oscilloscope. Repeat after connecting a load. a. Apply a 12V peak to peak sine wave to the rectifier. Confirm all voltages in the wave have become positive. b. After connecting capacitor at rectifier output, confirm voltage fluctuation is less than 1V. c. After connecting regulator to setup so far, confirm output is 5VDC.
3. User interface sends signals (5V) for + and – when pushbuttons are pressed and each LED lights up when 5VDC is applied.	3. Connect 5VDC input power to control panel. Using a multimeter, confirm the output of each pushbutton is 5V when pressed. Also, apply 5V to each LED and confirm that they all light up.
4. Induction Machine must be able to work as a generator when shaft is driven over 1800RPM.	4. Measure the power at the terminals of the induction machine with a multimeter. Apply grid power to the machine. Drive the shaft at 1830 RPM with a dynamometer and confirm that electric power is generated.
5. When pedals are turned more than one rotation in continuous motion, the machine turns on. Then, pedaling at more the 60RPM, power is generated.	5. Confirm visually that LED's from the LED tension level light up with presses of the + pushbutton (10 presses turn on the next LED). When the shaft of the

When pedaling is stopped, machine turns off. a. Micro Controller output yields 5V on logic high and 0V on logic low. b. Micro Controller input variables are set when input signal is received. c. Micro controller PWM yields a PWM signal with 25%, 50%, 75% duty cycles. d. Servo can position itself anywhere in a 360 degree range of rotation. e. Variac must yield different voltage levels. Percentages of voltages must correspond to the percentages read in the dial of the vairac. Test for 25%, 50%, 75%, 100%. f. Hall-effect sensor must measure speeds that correspond, within 5% accuracy, to the speed of the shaft of the motor. Read values with a printf() function call from the microcontroller.	machine is turned more than 60 times, apply 3 phase power to the induction machine. When running the machine, test at different voltage levels (58V, 115V, 173V, 230V). Run shaft at 1875 RPM with a dynamometer and confirm power is generated by connecting a multimeter to the terminals of the machine. After 10-20 seconds stop all mechanical function by turning off the dynamometer. a. Make an LED blink from three different output pin. b. Use a push button on each input pin used. Change which LED blinks (from a.) each time a pushbutton is pressed. c. Connect the pwm output of the controller to an oscilloscope and measure 25%, 50%, and 75% duty cycle. d. Test the servo at 0, 90, 180, 270 and 360 degrees of rotation of the rotor. e. "When the shaft of the machine is turned more than 60 times, apply 3 phase power to the induction machine": turn variac, with the servo, to desired voltage level. Test variac at 58V, 115V, 173V, 230V. check voltage levels with a multimeter. f. Using printf command from microcontroller, compare speed of machine with speed measured by the Hall-effect sensor. Difference should be less than 5%.

6. Confirm ratio of rotation from induction machine to pedals is 30:1.	6. Using some mark on the shaft of the motor, slowly turn the pedals one rotation and count 30 rotations on the shaft of the motor.

Ethical Considerations:

- "to accept responsibility in making decisions consistent with the safety, health and welfare of the public, and to disclose promptly factors that might endanger the public or the environment"[1]
    - The induction machine only generates power when driven over synchronous speed. Below this speed, the machine will work as a motor. Unless proper precautions are taken, the machine would run on its own, whenever a user is not pedaling. To prevent possible injury due to this, logic will be included in the program so that only after the user begins to pedal will the machine turn on, and when they are done, the machine will turn off. A freewheel mechanism is also included to avoid injury in the short interval between the time when pedaling stops and the time when the machine turns off.

Citations:

- Prof. Carney. Senior Design Course Professor.
- Jim Kolodziej, Senior Design Teaching Assistant.
- Fitzgerald, A. E., et. al., Electric Machines, McGraw Hill, Fifth Edition, 1990.
- http://www.ti.com/solution/motor_control_high_voltage#, High-Voltage Motor Control Solutions from Texas Instruments.

[1] From the IEEE Code of Ethics

Schedule:

Week	Task
February 6	• Research Parts • Determine which parts can be obtained from the ECE department • Finish proposal • Begin Design Review
February 13	• Sign-up for Design Review • Order parts • Obtain parts provided by ECE department • Select controller and design control system (flow chart & logic) • Complete Design Review
February 20	• Get necessary requests to Machine Shop • Setup and test controller
February 27	• Setup and test Generator Control
March 5	• Integrate User Interface • Testing and Tolerance Analysis
March 12	• Complete physical setup (construction) • Prepare charts and graphs of results • Prepare for mock-up presentation
March 26	• Design and order PCB • Mock-up Demo
April 2	• Write Final Report • Mock-up Presentation • Assemble and test PCB (if finished)
April 9	• Assemble and test PCB (if not already done) • Prepare for final presentation
April 16	• Casings (cycle, control panel, etc.)
April 23	• Demo
April 30	• Final Presentation • Checkout

Cost Analysis:
Ideal salary: $30/hour
Hours spent: (15 hours/week) * (11 weeks) = 165 hours
Labor: ($30/hour) * (165 hours) * 2.5 = $12375.00

Parts:

Part no.	**Description**	**Price per unit ($)**	**Qty.**	**Total ($)**
---	Frame	100.00	1	100.00
MTR-P33-3BD18	3-phase 0.33HP 1800RPM 208-230/460V Induction Machine	96.00	1	96.00
MSP430F47196	Micro Controller	7.70	1	7.70
13435	NEW # 264 Hub City 25:1 Gear Box	85.00	1	85.00
---	Red LED	0.12	2	0.24
MV57 164 821 H	10x1 LED array	1.95	1	1.95
W02G 220C	Rectifier	0.48	1	0.48
LM7805AC	5V regulator	0.40	1	0.40
S41 908	Hall effect sensor	1.93	1	1.93
---	Push button	2.00	2	4.00
TOTAL				297.70

Total cost: $12672.70