ISSN: 2633-4828 Vol. 5, No.3, September, 2023

International Journal of Applied Engineering and Technology

PI Arduino for a Bucket Milking Machine Speed Control

Bopit Bubphachot[1], Apinan Aurasopon[2]

[1,2]*Faculty of Engineering, Mahasarakham University, Kantharawichai district, Maha Sarakham, Thailand, 44150.*

[1]bopit.b@msu.ac.th, Corresponding author: [2]apinan.a@msu.ac.th

Date of Submission: 1st July 2023 Revised: 10th August 2023 Accepted: 22th August 2023

How to Cite: **Bopit Bubphachot and Apinan Aurasopon (2023), PI Arduino for a Bucket Milking Machine Speed Control, International Journal of Applied Engineering Research 5(3), pp.33-40**

Abstract - **This study addresses the issue of power loss in bucket milking machines caused by using a traditional AC motor running at full speed to create vacuum levels in the milking system. To mitigate this inefficiency, we propose a speed control system for the milking machine, enabling the motor to operate more efficiently relative to the vacuum level required for milking.Our system utilizes a pressure sensor module to measure the vacuum level within the milking system. The collected data is then processed by a Proportional-Integral (PI) controller, implemented through an Arduino board, to generate a control signal. This signal is fed into a Sinusoidal Pulse-Width Modulation (SPWM) module, which regulates the motor's speed with a fundamental voltage proportional to the fundamental frequency (Volts per Hertz, V/Hz).Through this control approach, the vacuum pump motor's speed is finely tuned to match the desired vacuum level, thereby reducing power consumption and avoiding the losses encountered in traditional regulator control systems.**

To validate the effectiveness of our proposed method, we conducted tests on a bucket milking machine with a 1-phase motor rated at 746 watts and a speed of 1,440 rounds per minute (rpm), using electric power as an indicator.The experimental results clearly demonstrate that our speed control system outperforms the conventional regulator control system by consuming less power. Moreover, the proposed system showcases its adaptability in compensating for extrusion pipe leaks. In case of a leak, the control system adjusts the motor speed to maintain a constant vacuum level, ensuring the smooth operation of the milking process.

Index Terms - **Bucket milking machine, PI controller, Arduino, SPWM, inverter.**

INTRODUCTION

Milking machines play a crucial role in modern dairy farming by efficiently extracting milk from cows through the application of vacuum pressure on their teats. These machines not only save valuable time and costs for farmers but also contribute to maintaining consistent milk quality.

To ensure the optimal performance of milking machines, adherence to international standards for installation, operation, maintenance, testing, and functionality is imperative. The design of a milking machine hinges significantly on determining the appropriate vacuum level. This involves the use of a vacuum pump capable of creating a vacuum of approximately 45-50 kPa within a closed pipe, which is then reduced to a standard range of 37-42 kPa through a regulator. Traditionally, this requires the vacuum pump motor to operate at full speed, leading to energy wastage [1]-[2].

To address this energy inefficiency, frequency inverters are employed to control the speed of the pump motor based on the detected vacuum level. The primary objective is to reduce electric energy consumption while maintaining a consistent vacuum level. By programming desired vacuum levels, the inverter detects any deviations in vacuum pressure near the sensor and promptly adjusts the motor speed to achieve the target values. Conversely, the inverter decreases motor and pump speed when the system experiences reduced air intake, thus lowering the vacuum level. Extensive research has investigated the efficiency and energy consumption of variable versus full-speed vacuum pump systems [3]-[5]. In some studies, the application of an optimal proportional and integral controller (PI controller) within the feedback system was explored [6]. However, there is currently a lack of research on designing a variable speed control system with an introduced PI control utilizing Arduino technology specifically tailored for bucket milking machines.

Addressing this research gap, this paper presents a variable speed control system designed for a bucket milking machine, catering to the needs of small dairy farms in Thailand. The proposed system incorporates a single-phase inverter and a sophisticated control mechanism. Experimental results demonstrate the system's capability to effectively regulate pump speed in response to vacuum levels.

The subsequent sections provide a comprehensive overview of the conventional bucket milking machine, the intricate details of the proposed system including inverter control circuits, PI controller employing Arduino and SPWM and driver circuits, the experimental findings comprising pump motor speed versus vacuum level and power consumption, discussion and finally, concluding remarks on the work presented.

BUCKET MILKING MACHINE

Figure 1 illustrates the key components of a bucket milking machine, comprising:

Vacuum Pump and Motor: The vacuum pump, powered by a motor running at full speed, efficiently removes air from a closed pipe, resulting in a pressure lower than the surrounding atmosphere.

Vacuum Regulator: Functioning as a control valve, the vacuum regulator reduces the fluid pressure to the optimal level at the output stage. This is achieved by skillfully managing the opening and closing of valves to control the airflow.

Pulsators: Pulsators are responsible for rhythmic pulsation of the teat liners, causing them to alternately open and close on the teat at one-second intervals. This pulsation is facilitated by connecting the pulsation chamber of the teatcups to either vacuum or atmosphere.

In the system design process, a primary consideration is given to the vacuum pump's capacity for effectively drawing air from the milking system. As described by equation (1), the volumetric flow rate of air per minute is directly related to the motor speed (measured in rpm), which, in turn, corresponds to the vacuum level [7].

$$\text{Volumetric Flow Rate of Air/Minute} = (\pi R^2 h - \pi r^2 h) \times rpm \quad (1)$$

VARIABLE SPEED CONTROL FOR THE BUCKET MILKING MACHINE

This section delves into the intricacies of the variable speed control system designed for the bucket milking machine.

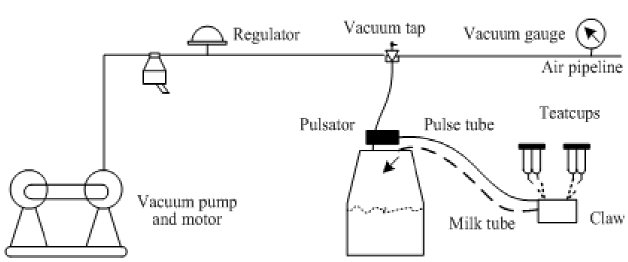


Figure 1 A Bucket Milking Machine Type

I. Block diagram of variable speed control operation

Figure 2(a) illustrates the block diagram of the variable speed control system employed in the bucket milking machine. It comprises three main components:

Bridge Diode Rectifier Circuit: This circuit is responsible for converting the incoming AC voltage into a stable DC bus voltage of 310 Vdc.

LC Filter Circuit: The LC filter ensures the DC bus voltage remains constant, contributing to a smooth and reliable power supply.

Single Bridge Inverter Circuit: This circuit plays a vital role in converting the DC voltage back to AC voltage, enabling its application to drive the AC motor.

On the other hand, Figure 2(b) portrays the control system responsible for generating the Pulse-Width Modulation (PWM) signals. These signals dictate the ON and OFF time periods of power switch within the system. The outcome of this process is a sinusoidal AC output voltage, denoted as v_o, which directly influences and controls the speed of the AC motor. This relationship between the AC motor's speed and the vacuum level is pivotal for achieving efficient and adjustable milking operations.

II. Block diagram of variable speed control operation

The control system comprises negative feedback to measure pipeline vacuum, a PI controller for generating a control signal, an SPWM modulator for PWM signal generation, and driver circuits for controlling power switches (M1-M4).

- *Vacuum measurement circuits*

To effectively control the air in the pipeline, the analog pressure sensor module XGZP6847A is chosen due to its excellent linearity, stability, and sensitivity, which are depicted in Fig. 2(b). The sensor operates with a 5Vdc supply voltage, and its output voltage, v_{feed}, ranges from 0.5V to 4.5V, corresponding to the vacuum range of -100 to 0 kPa [8].

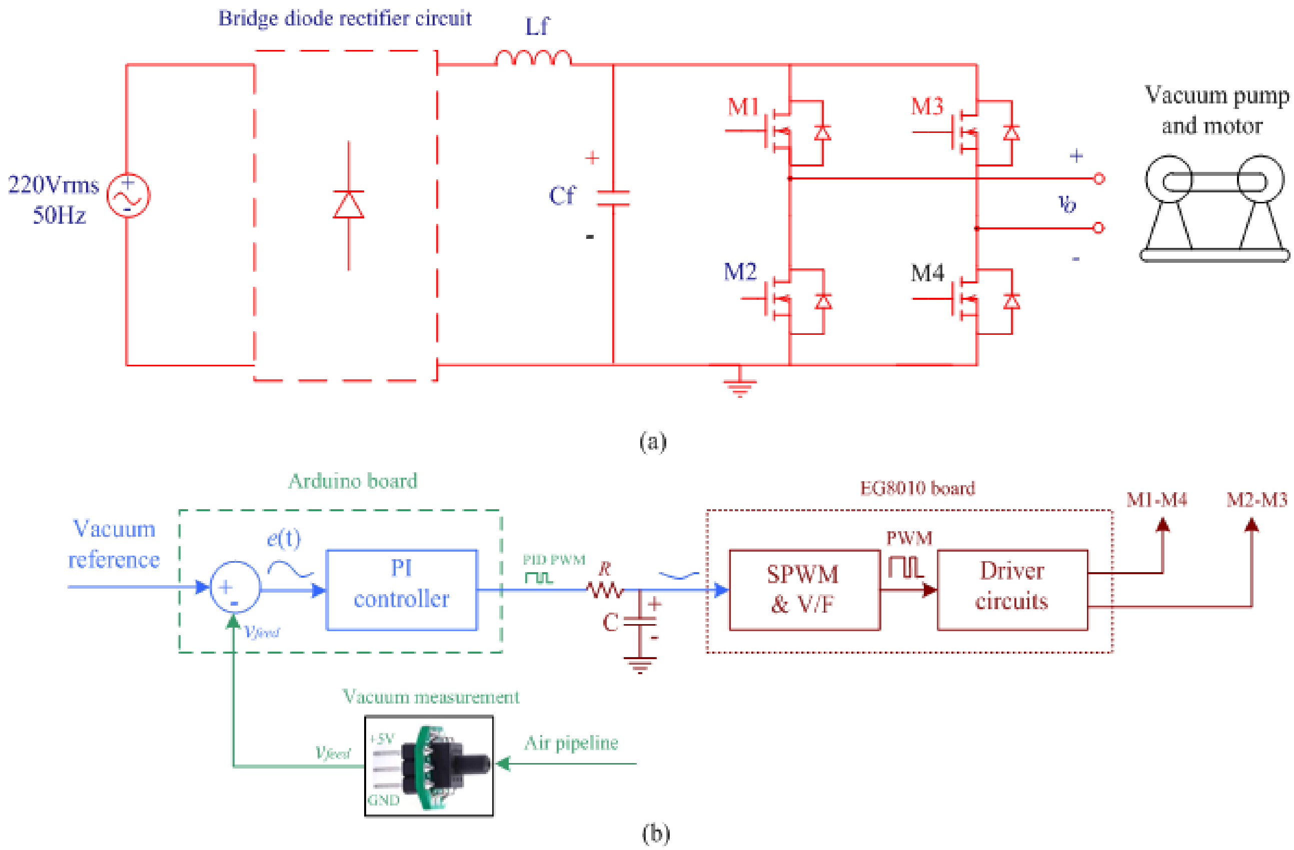


Figure 2 (A) Block Diagram Of Variable Frequency Control For The Bucket Milking Machine And (B) Its Control System.

- *PI controller by Arduino*

The PI controller operates by constantly computing an error voltage, *e*(t), derived from the difference between a reference voltage, v_{ref}, and the measured vacuum level, v_{feed}. It then employs both proportional and integral terms to apply appropriate corrections. The mathematical expression presented here represents the controller in continuous time or in the analog domain [9]-[10].

$$u(t) = k_p e(t) + k_i \int_0^t e(t)dt \quad (2)$$

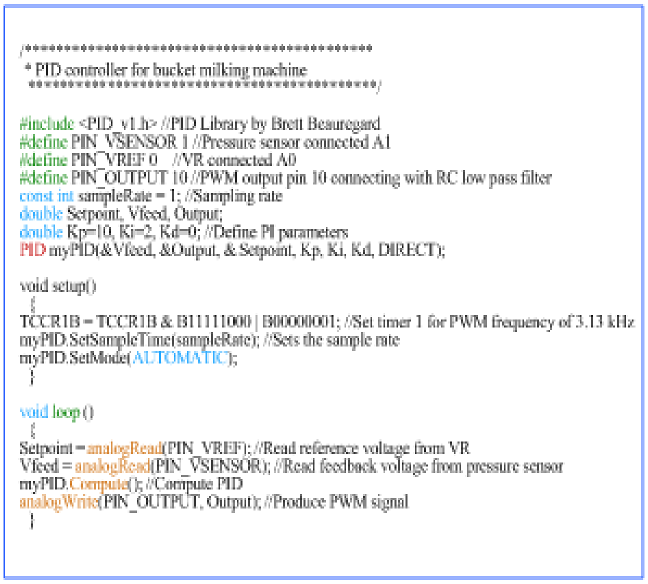
The equation (2) represents the PI controller in continuous time, while equation (3) demonstrates its conversion to the discrete time or digital domain.

$$u(n) = k_p * e[n] + k_i * \sum_{k=0}^{n} e[k]T \quad (3)$$

In the digital domain, the controller can be implemented using a microcontroller like Arduino with the help of Brett Beauregard's PID library. To achieve this, specific PID parameters, $k_p$and k_i, need to be specified.

The setpoint, v_{ref}, and feedback voltage,v_{feed}, are obtained through analog functions, reading from the variable resistor and pressure sensor, respectively. The implementation process is illustrated in Fig. 2.Therefore, PI controller can be implemented digitally or with a microcontroller like Arduino using software, as illustrated in Fig. 3. To facilitate this implementation, the Brett Beauregard's PID library can be utilized, requiring the specification of PID parameters $k_p$and k_i.

In the digital implementation, the set point, v_{ref}, and feedback voltage, v_{feed}, are acquired using analog functions to read the values from the variable resistor and pressure sensor, respectively. By continuously calculating the error voltage based on the difference between v_{ref} and v_{feed}, and applying proportional and integral terms, the PI controller can effectively regulate and control the system's behavior to maintain the desired vacuum level. The use of Arduino and the PID library makes it easier to achieve accurate and precise control in real-time milking machine operations.



```
/************************************************
 * PID controller for bucket milking machine
 ************************************************/

#include <PID_v1.h> //PID Library by Brett Beauregard
#define PIN_VSENSOR 1 //Pressure sensor connected A1
#define PIN_VREF 0    //VR connected A0
#define PIN_OUTPUT 10 //PWM output pin 10 connecting with RC low pass filter
const int sampleRate = 1; //Sampling rate
double Setpoint, Vfeed, Output;
double Kp=10, Ki=2, Kd=0; //Define PI parameters
PID myPID(&Vfeed, &Output, & Setpoint, Kp, Ki, Kd, DIRECT);

void setup()
  {
TCCR1B = TCCR1B & B11111000 | B00000001; //Set timer 1 for PWM frequency of 3.13 kHz
myPID.SetSampleTime(sampleRate); //Sets the sample rate
myPID.SetMode(AUTOMATIC);
  }

void loop ()
  {
Setpoint = analogRead(PIN_VREF); //Read reference voltage from VR
Vfeed = analogRead(PIN_VSENSOR); //Read feedback voltage from pressure sensor
myPID.Compute(); //Compute PID
analogWrite(PIN_OUTPUT, Output); //Produce PWM signal
  }
```

Figure 3 Code For PI Arduino

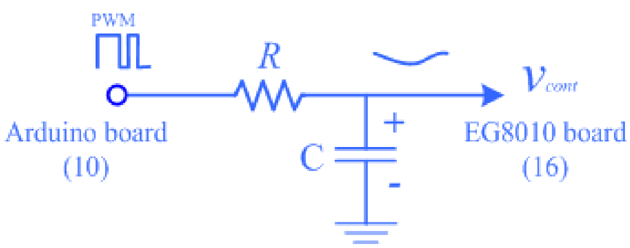


Figure 4 Control Signal Generation

- *Control signal PI*

To bridge the gap between the PWM signal output from the Arduino board (PIN 10) and the requirement of the SPWM board (EG8010) for an analog control signal ranging from 0 to 5V, a low-pass RC filter circuit is employed, as depicted in Fig. 4. The low-pass RC filter works to smooth out the PWM signal and convert it into an analog signal with a voltage range of 0 to 5V. This filtered analog signal is then suitable for controlling the fundamental output frequencies of the SPWM board, enabling precise and efficient speed control of the AC motor in the bucket milking machine. The integration of the low-pass RC filter ensures seamless communication and compatibility between the Arduino and the SPWM board, facilitating a well-coordinated speed control system.

- *SPWM and driver circuits*

Various methods have been employed to control the speed of AC motors. One simple and widely used control algorithm is the Volts per Frequency (V/F) control mode, particularly prevalent in pump and fan systems.

The V/F control mode ensures a constant motor flux, effectively preventing issues such as weak magnetic fields and magnetic saturation phenomena from occurring [11]. To implement V/F control, a digital pure sine inverter ASIC board is selected, as depicted in Fig. 5. This board features the EG8010 IC, which integrates key components like the SPWM sinusoidal generator, dead-time control circuit, soft-start circuit, and circuit protection. Additionally, the board incorporates two IR2113 ICs responsible for driving the four power switches essential for controlling the AC motor's speed [12]. The combination of V/F control and the digital pure sine inverter ASIC board provides an efficient and reliable means of regulating the motor's speed, making it suitable for a variety of applications, particularly in systems like pumps and fans.

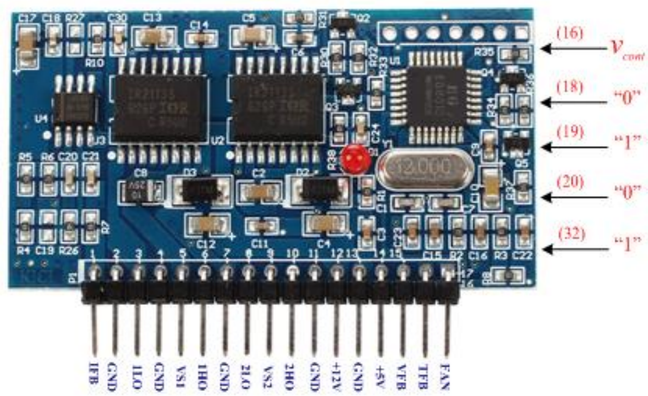
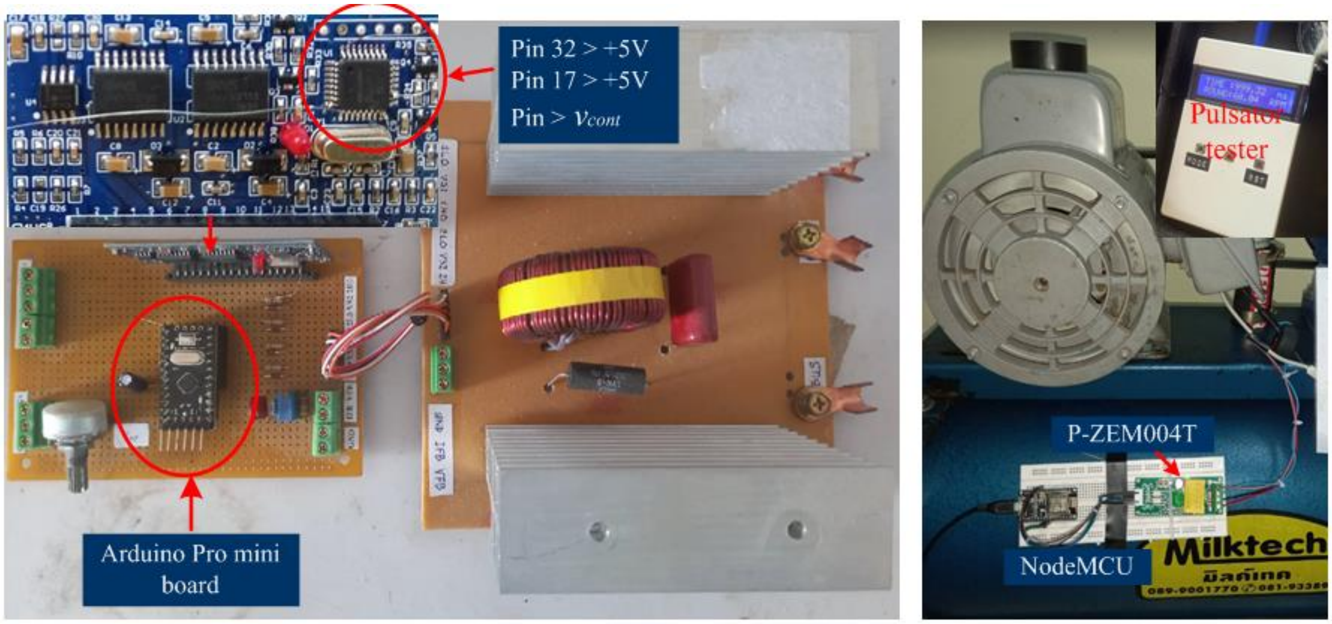


Figure 5 EG8010 Module

In the configuration of the board module, it is initially set to operate in constant voltage and frequency modes, with specifications at 220V and 50Hz. To switch to variable voltage variable frequency mode, the pins of EG8010 are adjusted as follows:

- *Pin 16 (FRQADJ):* This pin is utilized to adjust the frequency. By applying a control voltage, v_{cont}, ranging from 0 to 5V, the fundamental wave output frequency can be set within the range of 0 to 100 Hz.
- *Pins 18 and 19 (FRQSEL1 and FRQSEL0):* These pins are employed to set the frequency mode. For achieving an output frequency between 0 to 100 Hz, they are configured as "10".
- *Pin 20 (MODSEL):* To enable the unipolar modulation mode, this pin is set as "0".
- *Pin 32 (VVVF):* The variable voltage variable frequency function is enabled by setting this pin to "1".

The connections between pins 1-16 of the board module are established with the inverter circuit provided by [12]. With this setup, the board module operates in variable voltage variable frequency mode, allowing precise control over the motor's speed, making it suitable for applications requiring varying speed operations in the 0 to 100 Hz range.



(A) (B)

Figure 6 (A) Prototype Of Variable Speed Control And (B) Measurement Tools Eg8010 Module

EXPERIMENTAL RESULTS

I. Experimental setup

In this section, we present the experimental results of the speed control system for the bucket milking machine, which was set up with the following specifications:

- Bucket Milking Machine:
  Vacuum Pump Power: 746W
  Suction Capacity: 220 l/min
  Normal Voltage: 220Vrms, 50Hz
  Pump Speed: 1,440 rpm
- Parameters of the PI Controller in the Digital Domain:
  Proportional Gain (k_p): 10
  Integral Gain (k_i): 2
- Filter Circuit:
  Capacitor (C): 220µF
  Resistor (R): 1.8kΩ
- Inverter Circuit:
  Power MOSFET: IRFP450

The experimental results showcase the performance of the speed control system, providing insights into the motor's response to varying vacuum levels and its ability to maintain a stable and desired operating speed. By employing the PI controller with the specified gains, the digital implementation ensures precise and efficient control over the motor's speed, allowing it to meet the demands of the milking process effectively.

Additionally, the performance of the filter circuit and inverter circuit are evaluated to ensure their successful integration into the system. The use of power MOSFETs like IRFP450 allows for reliable and robust control of the motor speed, further enhancing the overall efficiency and stability of the bucket milking machine.

Figure 6(a) presents the prototype of the variable speed control system designed for the bucket milking machine. The system comprises three main components:

- *PI Controller:* Implemented using an Arduino Pro Mini board with specifications of 5V and 16MHz, the PI controller plays a crucial role in regulating the motor's speed based on the measured vacuum levels.
- *Modified EG8010 Board Module:* This board module is customized and adjusted to operate in variable voltage variable frequency mode, allowing precise control over the motor's speed according to the desired vacuum levels.
- *Inverter Circuit:* The inverter circuit utilizes power MOSFETs, specifically the IRFP450, to effectively control the AC motor's speed based on the signals generated by the EG8010 board module.
- In Figure 6(b), two additional devices are featured for measurement purposes:
- *Pulsator Tester:* This tester is utilized to measure the vacuum level within the system, providing essential feedback for the PI controller to maintain accurate speed control.

- *PZEM004T AC Digital Power Energy Meter Module:* This module is employed to measure various parameters, including voltage, current, power, and energy, providing valuable insights into the system's energy consumption and overall performance [13].

The combined setup of these components in the prototype facilitates a comprehensive and efficient speed control system for the bucket milking machine, ensuring optimal milking operations while closely monitoring and managing energy consumption.

II. Measurement results for speed control system

In the experimental results, Figure 7 illustrates the PWM output from the Arduino board alongside the corresponding control voltage, v_{cont}. The PWM output represents the digital signal generated by the Arduino to control the EG8010 board module, while the control voltage, v_{cont}, is the analog signal used to adjust the fundamental output frequency in the V/F control mode.

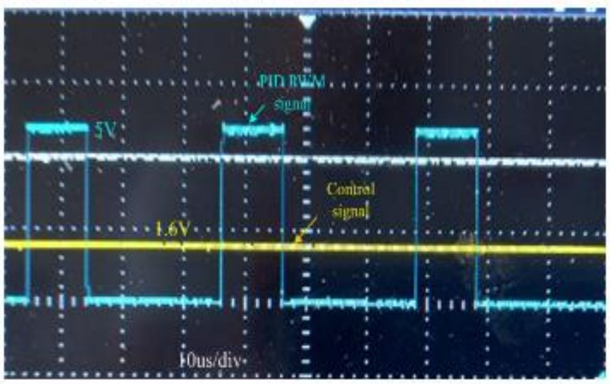


Figure 7 PID PWM And Control Signals

Figure 8 displays the outcomes of the variable speed control system based on V/F control at two different output frequencies: 50 Hz and 43 Hz. At 50 Hz, the sinusoidal output voltage is 220Vrms, resulting in a vacuum pump speed of 545 rpm and a vacuum level of 50 kPa. Similarly, at 43 Hz, the sinusoidal output voltage is 195Vrms, leading to a vacuum pump speed of 475 rpm and a vacuum level of 42 kPa. Through this V/F control process, the system effectively regulates the speed of the vacuum pump, achieving the desired vacuum levels for the bucket milking machine. The experimental results demonstrate the successful operation and performance of the variable speed control system, validating its capability to maintain consistent and precise milking conditions.

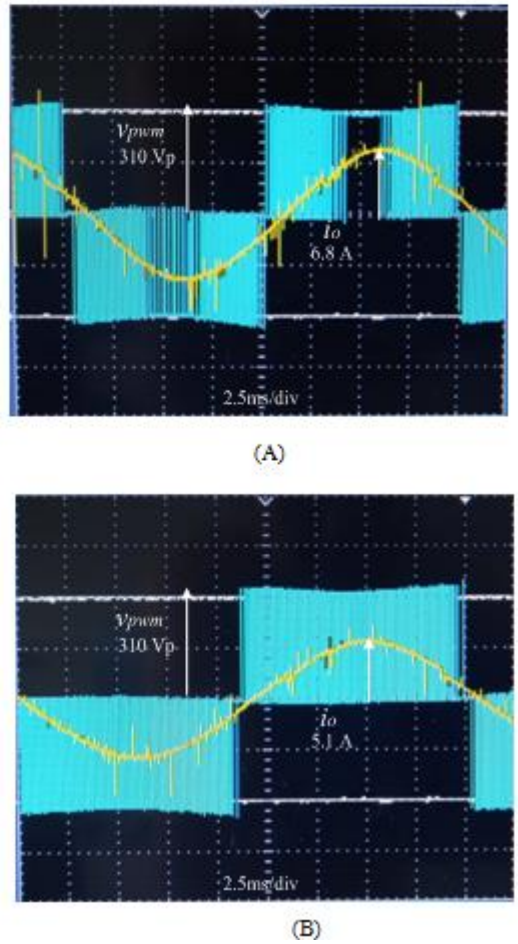


Figure 8 Wave Forms Of v_{pwm}And i_o (A) Output Frequency 50HZ And (B) Output Frequency 43 HZ.

Figure 9 presents the results of the vacuum level variation in the pipeline concerning the vacuum pump speed, measured at a steady-state vacuum level. In the case of conventional or fixed speed control, with a nominal voltage and frequency of 220 Vrms and 50 Hz respectively, the vacuum pump operates at its full speed of 545 rpm, resulting in the maximum vacuum of 65 kPa. However, when the regulator valve is adjusted to decrease the vacuum level in the pipeline to 50, 45, 40, and 35 kPa, the vacuum pump continues to run at its full speed of 545 rpm. This leads to unnecessary energy wastage. To address this energy inefficiency and save power, the speed of the vacuum pump motor should be reduced when the vacuum level decreases. This is achieved through variable speed control, where the regulator is removed. As depicted in Figure 9, when the vacuum level decreases, the vacuum pump speed is also reduced accordingly.

For instance, at the standard vacuum level of 45 kPa, the pump speed is lowered to 380 rpm. This demonstrates that the energy supplied to the motor is effectively reduced, leading to energy savings and improved efficiency in the system.

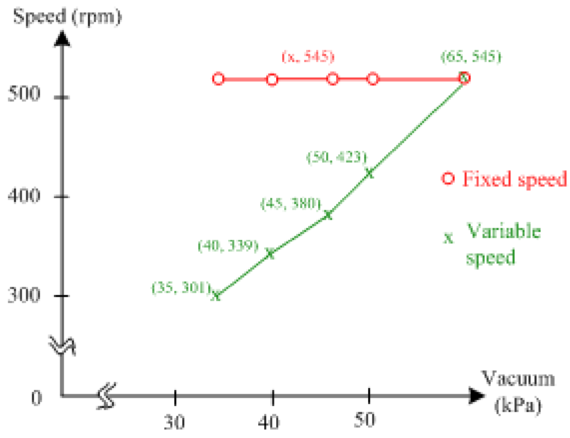


Figure 9 Vacuum Level Versus Motor Speed

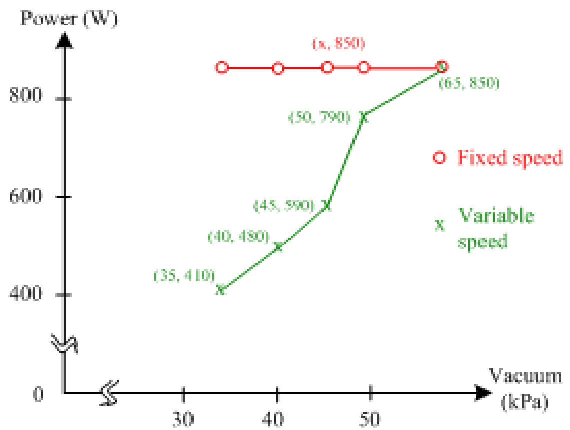


Figure 10 Vacuum Level Versus Power Consumption

In Figure 10, the measurement results for the power consumption of the pump motor are displayed in relation to the vacuum level. When the variable speed control is not utilized, and the motor operates at full speed, its power consumption remains consistently high at 850 W for all vacuum levels. However, when the V/F control is applied, particularly in the low vacuum level range, the power consumption notably reduces compared to that of the fixed speed control. This demonstrates the energy-saving advantage of employing the variable speed control system. By adjusting the motor speed according to the vacuum level, the variable speed control effectively optimizes energy usage, resulting in lower power consumption during the milking process. These results validate the benefits of implementing variable speed control in the bucket milking machine, showcasing its potential to reduce power wastage and enhance overall system efficiency, particularly in scenarios with varying vacuum levels.

The experimental results clearly demonstrate the advantages of the variable speed control system over the fixed speed control system.

Not only does the variable speed control system save electrical energy, as shown by the reduced power consumption compared to the fixed speed control, but it also exhibits an important capability to maintain a constant level of vacuum despite pressure pipe leaks. In the experiments, when the pressure pipe was intentionally set to leak at 20% of its full openness, the vacuum level decreased to 35 kPa in the case of the fixed speed control system. However, the variable speed control system was able to adapt to the leak and counteract the vacuum decrease. By increasing the speed of the vacuum pump to 410 rpm, it successfully maintained the desired vacuum level of 45 kPa.

This ability to adjust the motor speed in response to changes in the vacuum level not only saves energy under normal operating conditions but also proves valuable in handling unexpected situations like pressure pipe leaks. The variable speed control system's versatility and efficiency make it a highly effective solution for the bucket milking machine, ensuring consistent performance and energy savings even in dynamic conditions.

DISCUSSION

The variable speed control system demonstrated clear energy-saving benefits over the conventional fixed speed control. By adjusting the motor speed based on the vacuum level, the system reduced power consumption, leading to more efficient energy utilization during the milking process. This not only contributes to cost savings for the dairy farmer but also aligns with the growing emphasis on sustainable and eco-friendly practices.The variable speed control system exhibited precise regulation of the vacuum level within the milking pipeline. Unlike the fixed speed control system, which struggled to maintain a constant vacuum level in the presence of pressure pipe leaks, the variable speed control system effectively compensated for such deviations. This ensures consistent milking performance, optimizing milk extraction and reducing the risk of potential harm to the cows.By maintaining a constant vacuum level and adjusting motor speed accordingly, the variable speed control system contributes to improved milking efficiency. This not only streamlines the milking process but also enhances milk quality and overall productivity on the dairy farm.The integration of microcontrollers like Arduino, PWM modulation, and the EG8010 board module demonstrates the successful implementation of advanced technology in the milking machine. The use of these technologies facilitates sophisticated control algorithms and real-time adjustments, ensuring smooth and precise motor speed control.Overall, the discussion underscores the significance of the variable speed control system in modernizing milking practices and aligning with sustainable and efficient dairy farming methods.

The successful application of this technology in the bucket milking machine holds promise for optimizing milking processes, reducing environmental impact, and ultimately benefiting both dairy farmers and their livestock.

CONCLUSIONS

This paper successfully presented the design and experimental evaluation of the variable speed control system for the bucket milking machine. The system integration involved feedback control, SPWM (V/F) technology, and a full-bridge inverter circuit. To compare its performance, two systems, namely regulator or fixed speed control and variable speed control, were extensively tested with the bucket milking machine. The experimental results highlighted the superiority of the variable speed control system in various aspects. Firstly, it demonstrated significant energy savings compared to the fixed speed control system, confirming its efficiency and potential for cost reduction. Secondly, due to the incorporation of feedback control, the variable speed control system effectively maintained a constant vacuum level, even when pressure pipe leaks were introduced. This adaptability and resilience in maintaining the desired vacuum level are crucial for consistent milking performance and ensuring the well-being of the cows. Overall, the paper's findings emphasize the benefits of implementing variable speed control in bucket milking machines. This technology not only enhances milking efficiency but also promotes sustainable and eco-friendly practices by reducing energy consumption. The successful integration of advanced control algorithms, microcontrollers, and inverter technology demonstrates the potential of modernizing milking processes and optimizing dairy farm operations.

ACKNOWLEDGMENT

This research project is financially supported by Mahasarakham University.

REFERENCES

[1] ASAE. (1996). Milking machine installations-construction and performance, ASAE Standards S.518.1 MAR94, St. Joseph, Michigan.

[2] Richard Laven. (2021). Mastitis Part 9 - The Milking Machine, NADIS animal health skills, 1-3.

[3] Guo, F, DC Ludington, DJ, Aneshansley, and RA Pellerin. (1991). Control vacuum pump speed for vacuum stability, ASAE Annual International Meeting 1991 Technical paper, 91, 3022.

[4] Fryč J., Kudělka J. and J. Los. (2018). Vacuum control of milking machines by using the frequency converter and the reducing valve, International scientific journal "MECHANIZATION IN AGRICULTURE" , 64 (1), 15-17.

[5] Vaculik P., M. Prikryl, J. Bradna and L. Libich. (2018). Energy consumption of milking pump controlled

[6] Kudělka J, Fryč J, Slany´ V, Rousˇ R, Raj A, R. Martı´nek. (2021). Parameters setting of Frequency Converter PI regulation to ensure the vacuum of the milking process, PLoS ONE, 16(7), 1-17.

[7] Debora A. Costa, Douglas J. Reinemann and Pierre Billon. (2003). Design Considerations for Milking Machines Used in Brazil, 2003 ASAE Annual International Meeting, Paper Number: 033015, Las Vegas, Nevada, USA 27- 30 July 2003.

[8] CFSensor. XGZP6847A Pressure sensor module, CFSensor, www.CFSensor.com.

[9] Aaron Dahlen, THE PID CONTROLLER — PART 1, www.nutsvolts.com.

[10] Theophilus, E. E., Ismail, I., Fagbohun, O.O., and O. J. Femi-Jemilohun. (2018). Design of Analog PID Controller, J. of Advancement in Engineering and Technology, 7(1), 1-7.

[11] Jia X. M. and S. S. Choi. (2001). Design of Volts per Hertz limiter with consideration of the under-excitation limiter control actions, in IEEE Transactions on Energy Conversion, 16(2), 140-147.

[12] EGmicro corp. 2021. EG8019 Datasheets ASIC for single-phase SPWM control.

[13] Chiraphon, T. and A. Apinan. (2021). Monitoring system for a bucket milking machine based on IoT, International Journal of Engineering Trends and Technology, 69(9), 29-33.

AUTHOR INFORMATION

Apinan Aurasopon He received his B.Eng. degree in Electronics Engineering form the Northeastern College, KhonKaen, Thailand, in 1995, his M.Eng. and Ph.D. degree in Electrical Engineering from the King Mongkut’s University of Technology Thonburi, Bangkok, Thailand, in 2003 and 2007, respectively. He was a lecturer in the Department of Electrical Engineering, Faculty of Engineering, Burapha University, Chonburi, Thailand, in 2007. He was transferred to the Faculty of Engineering, Mahasarakham University, Mahasarakham, Thailand, in 2008, where he is currently an Associate Professor. His current research interests include soft-switched converters, power factor and the application of electronics and computer for agriculture.

Bopit Bubphachot received his Ph.D. degree in Engineering Mechanics and Energy from the University of Tsukuba, Japan, in 2008. He is currently an Associate Professor at the Faculty of Engineering at Mahasarakham University in Thailand. His’s research interests include Metal Forming (Fine Blanking Process), FEM Simulation in Metal Forming Process, Fatigue and Creep-Fatigue strength for Perforated Plate, Heat pipe, and Heat exchanger.