ZIGBEE BASED CONTROL STRATEGY FOR SPEED SYNCHRONIZATION OF MULTIPLE MOTORS

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Abstract: With the advancement of computer technology and digital systems, wireless control systems or Wireless Networked Control Systems (WNCS) are becoming increasingly popular among the scientific community as well as the industry due to their flexibility, convenience & ease of operation. In this project, a closed-loop discrete time system for speed control of a permanent magnet DC motor with discrete PI controller is implemented in embedded platform. The design & analysis of the system is based on the mathematical model of the DC motor obtained by system identification technique. After that the closed loop system is distributed through a wireless network created by means of Bluetooth without any change in the discrete controller. The network connects the controller on one side with the sensor, actuator & the plant on the other side. In this project, optimal synchronization speed control of multiple DC motors is developed by using leader follower-based approach. One of the DC motors is considered as a leader motor and it tracks its desired speed trajectory. The other DC motor is controlled through a leader-follower based optimal formation controller developed in this work. If the leader DC motor slows down or speeds up for some reason, the follower DC motor synchronize its speed according to the leader without having any knowledge about the desired trajectory. By doing so, the multiple DC motors will be able to work together in a synchronized manner. The experimental and simulation results are given at the end of the thesis to verify the proposed theoretical claims.

Keywords: Renewable energy, Hybrid Microgrid, Battery Energy Storage, Particle Swarm Optimization.

I. Introduction

DC motor speed controllers are widely used for motion control of robotics, industrial control and automation systems. Industrial process control has requirements of adjusting motor speed over a wide range with good resolution and reproducibility. Conventional analog speed control methods have certain drawbacks, including nonlinearity in the analog speed transducer and difficulty in accurate transmission of the analog signal. Also in analog methods signal manipulation suffers from errors occurring due to temperature, component aging, and external disturbances. In a digital speed control scheme, there is no nonlinearity associated with speed transducer and the digital signal of speed can be transmitted to long distances without sacrificing accuracy. Also in a digital speed control system, the control signal is not adversely affected by temperature variations, component aging, or noise [1].

For the purpose of speed control of a DC motor, a variable-voltage DC power source (DC Chopper) is needed. Pulse Width Modulation (PWM) technique is used for generating variable voltage for speed control purpose. In home appliances the permanent magnet DC motor has replaced the ac universal motor due to improve speed or drive performance [2-4]. In this research, an embedded speed control method for a permanent magnet DC motor has been implemented in Arduino due to micro controller board based on the Atmel SAM3X8E ARM processor. The wired speed control scheme can also be implemented with two Arduino Due micro controller boards serially connected through wires as in figure 1.1.Then the controller side and plant side of the embedded control

system as in figure 1.2 are connected with a wireless network (Bluetooth) in order to develop a Wireless Networked Control System (WNCS). The motive of this research is to observe the performance of the closed loop system with wireless network and then develop necessary techniques or algorithms for performance improvement, if required. The advancement of semiconductor technology and electronic devices, the embedded micro controllers are very much inexpensive and can provide reasonably well speed of performance.

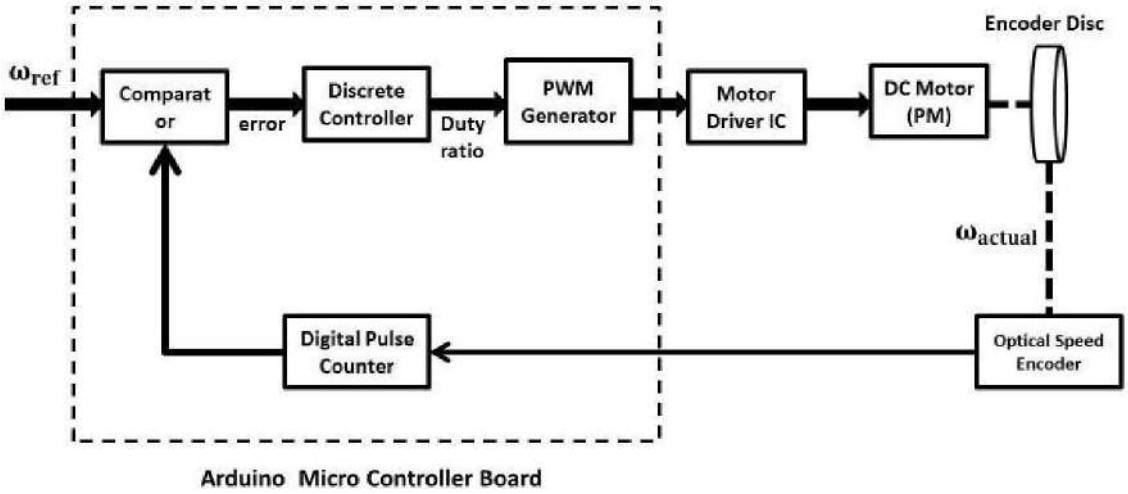


Figure 1 Block diagram of the basic embedded DC motor speed control system with single micro controller board

Wireless communication is the transfer of information or power between two or more points that are not connected by an electrical conductor.The use of a wireless network enables enterprises to avoid the costly process of introducing cables into buildings or as a connection between different equipment locations. So, it has gained widespreadpopularity with time and its use keeps growing. Wireless Networked Control System (WNCS) is a distributed control system with sensor, actuator and controller communication supported by a wireless network. WNCS can also be defined as a spatially distributed control system with sensor, actuator and controller communication sup- ported by a wireless network. WNCSs allow exchange of information among distributed sensors, controllers actuators over the wireless network to achieve certain control objectives.

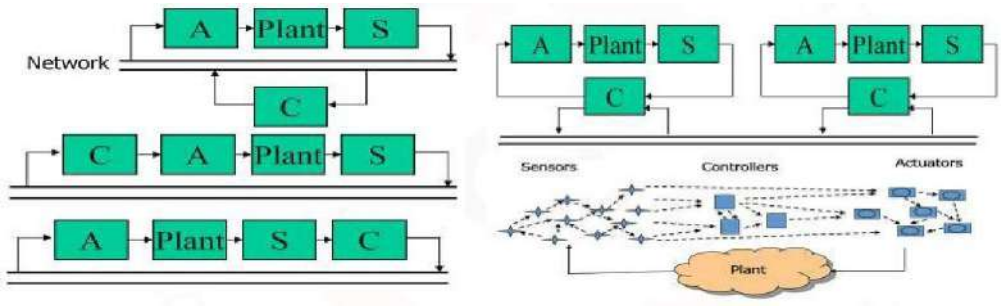


Figure 2 Wireless networked control systems

The benefits of wireless networked control are:

- It is more flexible.
- Sensors and actuators can be replaced easily.
- Less restrictive maneuvers and control actions.
- Powerful control over distributed computations.

- Reduction in installation and maintenance costs.
- Requirement of less cabling.
- Possibility of efficient monitoring and diagnosis.
- Wireless technology has some barriers in control and automation. Some of the key barriers of wireless technology are:
- **Complexity:** Systems designers and programmers need suitable abstractions tohide the complexity from wireless devices and communication.
- **Reliability:** Systems should have robust and predictable behavior despite characteristics of wireless networks.
- **Communication** of sensor and actuator data impose uncertainty, disturbances and constraints on control system.
- **Security:** Wireless technology is vulnerable to digital hacking or attacks.
    - Bandwidth limitations.
    - Data loss and bit errors.
    - Outages and disconnection.
    - Topology variations of different networks.
- There are several approaches to control in WNCS, they are,
- **Network-aware control:** Modify control algorithms to cope with communication imperfections, for e.g., predictive controller. In this procedure, in order to adjustcontrol algorithms, one needs to estimate the network states, like,
- Time Delay
- Data Loss
- Bandwidth
- **Control-aware networking:**Control of communication resources

The parameter of a wireless network which is of most concern is **time-delay**. Time de- lay in wireless communication arises due to the communication medium and additional functionality required for physical signal coding and communication processing.Time delay in a communication network is expressed as,

$T_{delay}=T_{device}+T_{network}$(1.1)

$T_{delay}=T_{pre}+T_{wait}+T_{prop}+T_{post}$(1.2)

Timedelayin acommunicationnetworkcanbeofdifferenttypesasgivenbelow

- Varyingorfixed.
- Knownorunknown.

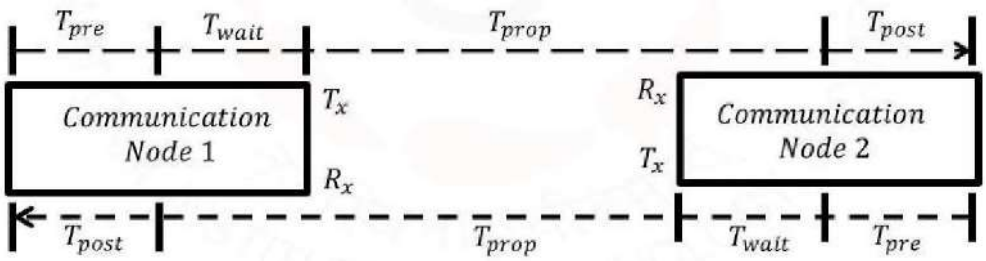


Figure 3: Break up of Communication Network Time-delay Into Different Constituents

1.2 Motivations

DC motor drives are widely used in applications requiring adjustable speed control, frequent starting, good speed regulation, braking and reversing. Some important applications are paper mills, rolling mills, mine winders, hoists, printing presses, machine tools, traction, textile mills, excavators and cranes. DC motors are widely used as servo motors for tracking and positioning. For industrial applications development of high-performance motor drives are very much essential. These applications may demand high speed control accuracy and good dynamic response. Some other examples of DC motor speed control applications are washers, dryers and other household appliances. Applications of DC motor speed control are also found in the automotive area for uses such as fuel pumps, electronic steering, and engine controls.DC motor drives are less costly and less complex compared to AC motor drives. Moreover, use of embedded systems for speed control purpose of DC motor brings the cost to much lower value. Development of very low-cost embedded speed control system can also serve as a good laboratory experiment to understand and learn control engineeringpractically.

1.3 Problem Statement

In this thesis, design of a closed-loop DC motor (permanent magnet) servo system for speed control will be discussed. Then implementation of the servo system using an embedded system platform (Arduino micro controller board) will be explained. The controller will be a discrete PI controller. Then the servo system will be distributed into two parts : controller side (containing reference input functionality, discrete controller and comparator) and plant side containing (actuator, sensor and the DC motor plant), with both the parts connected through a Bluetooth wireless network. The behavior of the wireless network in the control loop will be examined. Then the performance of the servo system with the wireless network will be observed.

1.4 Literature Review

DC motor speed control problem is an age-old problem that scientists and researchers are dealing with. There are lots of papers available in literature on DC motor speed control using various analog techniques and power electronic methods. Maloney, T.J. and Alvarado, F.L. (1976) [1] first discussed a digital method for DC motor speed control. A. K. Lin and W. W. Koepsel (1977) [2] first discussed a microprocessor (Intel 8080) based speed control strategy using DC chopper to achieve reasonably low steady state error. J. B. Plant and S. J. Jorna (1980) [3] published an SCR based dc motor drive control where a microprocessor performed both the control law computation and logical functions of SCR. State space methodology was used for the control purpose and stability, error analysis of the controller was provided. A. H. M. S. Ula, J. W. Steadman and J. M. Wu (1988) [4] explained a micro controller based speed control for industrial size DC motor using thyristors. J. Nicolai and T. Castagnet (1993) [5] discussed a permanent magnet DC motor speed control using micro controller generated PWM signal. Software flexibility for modifying drive parameters like maxi- mum power, time constant etc. Were also explained in that paper. T. Castagnet and J Nicolai (1994) [9] discussed a micro controller-based brush DC motor speed control through direct voltage compensation and motor power limitation. Y. S. E. Ali, S. B. M. Noor, S. M. Uashi and M. K. Hassan (2003) [6] explained a micro controller-based speed control and over current protection scheme for a DC motor. These are the key publications found in literature on embedded/ micro controller/ microprocessor-based DC motor servo systems.From the literature review, it has been found that most of the publications discussed simulation study of various smith predictor strategies for time delayed systems. Very few of them mentioned about practical implementation.

ZIBGEE CONTROLLER

[10:58 am, 23/06/2022] rajulapatigowthamipriya06: Zigbee is an IEEE 802.15.4-based specification for a suite of high-level communication protocols used to create personal area networks with small, low-power digital radios, such as for home automation, medical device data collection, and other low-power low-bandwidth needs, designed for small scale projects which need wireless connection. Hence, Zigbee is a low-power, low data rate, and close proximity (i.e., personal area [10:58 am, 23/06/2022] rajulapatigowthamipriya06: Its low power consumption limits transmission distances to 10–100 meters line-of-sight, depending on power output and environmental characteristics.[1] Zigbee devices can transmit data over long distances by passing data through a mesh network of intermediate devices to reach more distant ones. Zigbee is typically used in low data rate applications that require long battery life and secure networking. (Zigbee networks are secured by 128 bit symmetric encryption keys.) Zigbee has a defined rate of 250 kbit/s, best suited for intermittent data transmissions from a sensor or input device.

[11:01 am, 23/06/2022] rajulapatigowthamipriya06: Zigbee is a standards-based wireless technology developed to enable low-cost, low-power wireless machine-to-machine (M2M) and internet of things (IoT) networks.

Zigbee is for low-data rate, low-power applications and is an open standard. This, theoretically, enables the mixing of implementations from different manufacturers, but in practice, Zigbee products have been extended and customized by vendors and, thus, plagued by interoperability issues. In contrast to Wi-Fi networks used to connect endpoints to high-speed networks, Zigbee supports much lower data rates and uses a mesh networking protocol to avoid hub devices and create a self-healing architecture.

Zigbee specifications

Zigbee is based on the Institute of Electrical and Electronics Engineers (IEEE) Standards Association's 802.15 specification. Zigbee is built for control and sensor networks on the IEEE 802.15.4 wireless standard for wireless personal area networks (WPANs). The Zigbee WPANs operate on 2.4 Ghz, 900 MHz and 868 MHz frequencies.

The Zigbee specifications, which are maintained and updated by the Zigbee Alliance, boost the IEEE 802.15.4 standard by adding network and security layers in addition to an application framework.

The standards created by the alliance can be used to create multivendor interoperable offerings. Manufacturers that are developing custom applications that don't need to operate with the applications of other manufacturers can create their own specific variations and extensions.
[11:04 am, 23/06/2022] rajulapatigowthamipriya06: Zigbee is used by a variety of cable and telecommunication companies in their set-top boxes, satellite transceivers and home gateways to provide home monitoring and energy management products to their customers.

Zigbee is also used by vendors that provide connected lighting products for homes and businesses. With Zigbee-based smart home products, consumers can control LED figures, lightbulbs, remotes and switches in home and remotely to improve energy management.

Utility companies can use Zigbee in their smart meters to monitor, control, inform, and automate the delivery and use of energy and water. Smart meters give the consumers the information -- and automation -- needed to reduce energy use and save money.

Zigbee-based products also enhance the shopping experience for consumers by enabling faster checkouts, in-store assistance and in-store item location. Zigbee helps retailers operate more efficiently by ensuring items don't run out of stock and supporting just-in-time inventory practices, as well as monitoring temperatures, humidity, spills and so on.

Zigbee supports a number of devices, including intelligent shopping carts, personal shopping assistants, electronic shelf labels and asset tracking tags.

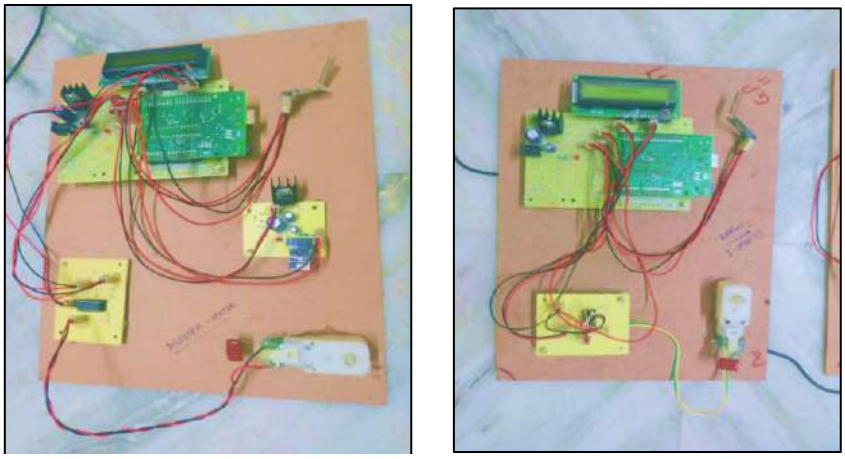


Figure 4 Hardware Implementation of Proposed Systems

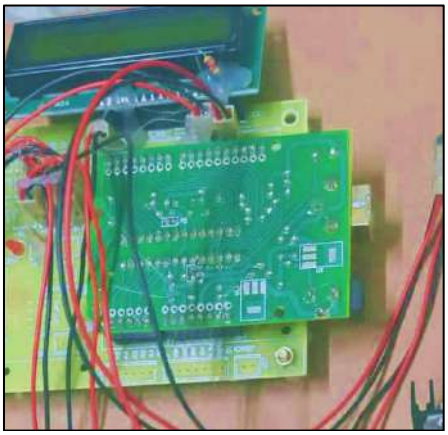
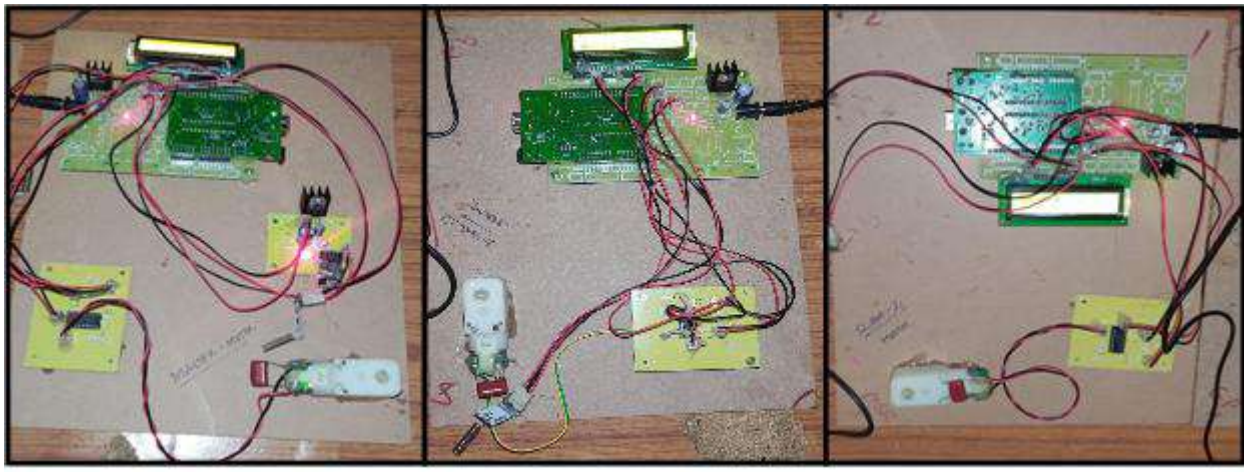
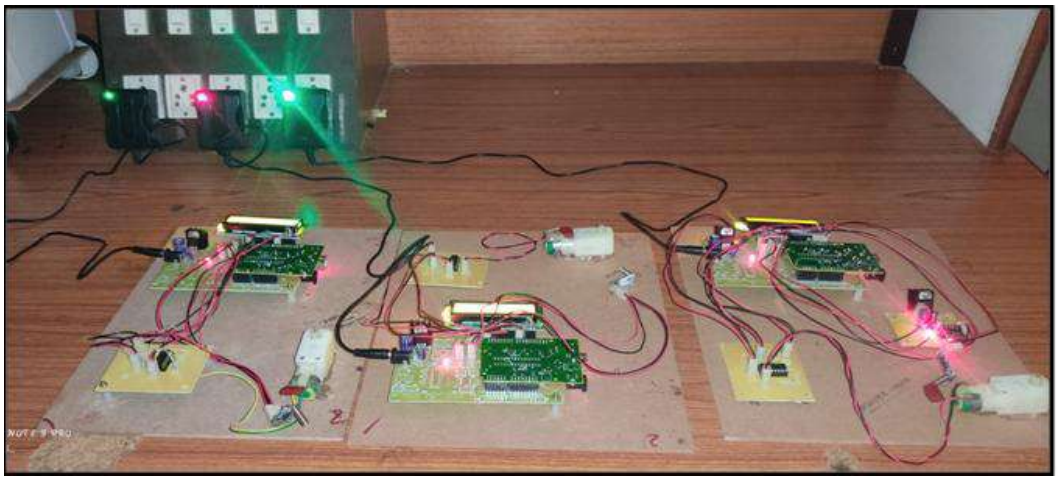


Figure 5 Arduino driver board of proposed system





CONCLUSION

Integrating features of all the hardware components used have been developed in it. Presence of every module has been reasoned out and placed carefully, thus contributing to the best working of the unit. Secondly, using highly advanced ICs with the help of growing technology, the project has been successfully implemented. Thus, the project has been successfully designed and tested. Software validation is verified through MATLAB/SIMULINK.

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