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Wirelessly programable actuators synchronous control

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Abstract :

Article describe questions and possible answers to many wirelessly controlled electromechanical actuators action synchronous control.

Keywords-wireless control; synchronous control; remotely controlled electromechanical actuators

I. INTRODUCTION

Electromechanical actuator wireless control are used in many cases and typically aren't critical to delays between command and actuator action - open/close the doors, turn on/off lights are common examples.

Delays between command and actuator action are caused by wireless serial communication and are determined by specific communication protocol and data transfer rate, in general. Delay time are variable, mainly in range of 0,5 - 5 seconds, according to provided experimental tests. To achieve synchronous action, some additional designs and add-ons must be applied.

This article describe one solution in area of synchronous control: mixed wired-wireless design. Future developments in "clear" wireless synchronous designs must be made.

In article are described design of 97, programmable through 4G/WiFi networks, actuators (12 V, DC) synchronous control system. Each actuator control large mirror vertical inclination. Mirrors, sized 2 x 2 meters each, are mounted on frame along one side of stadium as semi-animated decor (Fig.1). On 150 m wide and 24 m high frame are mounted 240 mirrors and 97 of them must change vertical angle, according to the show scenario: 3-6 inclination values for each controlled mirror during the show.

Several technical solutions are possible and known for actuators (here, more precisely - DC motors) control:

- motor feeding/control cable come to one place from each motor (star connection) - motors are in to a distance from motor controller. Here large cable cross-section must be applied to avoid significant voltage drop. Not possible to count screw turns without additional cable.
- applying separate 12 V battery for each motor and signal cables to each motor. Problematic solution due to large cable length and number, low communication speed, long installation time and separate battery charging lines must be provided.
- simple 433/868 MHz RxTx communication radio-link don’t offer micro-controller reprogramming on the fly, according to show scenario.
- only few of ZigBee chips or similar devices can be reprogrammed on the fly. Programming is complicated and devices aren’t low cost.
- WiFi modules, typically applied as extensions to micro-controllers, also doesn‘t allow to reprogram micro-controller on the fly.

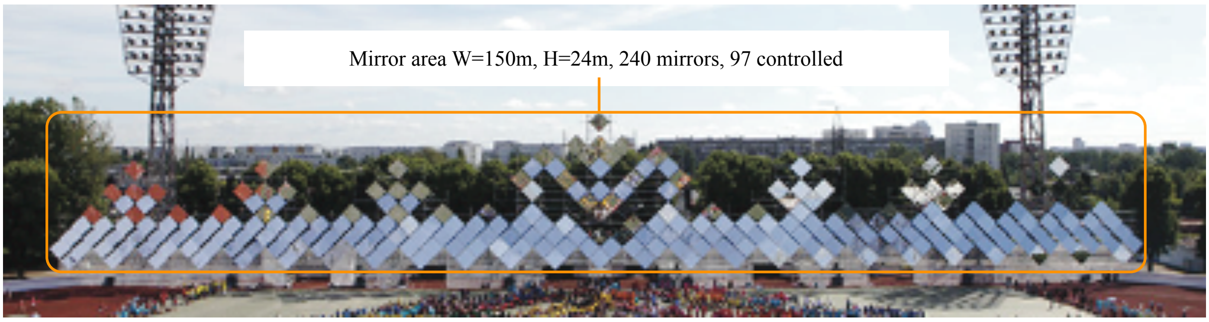

Fig.1. Installation main view

WiFi/internet, 433/868 MHz UART data transmission and ZigBee solutions are implemented and tested in to other works [2], [3]. As mentioned, for overall tasks time delay wasn't important and aren't taken into account. Here delays are important due to necessity of synchronous or semi-synchronous mirror movement, so proper system must be developed.

4G/WiFi networks, *imp* module [1], FileMaker Pro database, battery powered actuators and combined battery charging - synchronization circuit allow to create flexible control system, reduce micro-controller programming and system tuning time. Necessity to reach each mirror, mounted on vertical frame, to reprogram micro-controller, are excluded - all micro-controller code update can be done wirelessly.

II. ELEMENTS AND FUNCTIONAL DIAGRAM

A. Elements

As mentioned above, 97 mirrors must change vertical inclination according to the show scenario. Position are set by electromechanical module, each module include actuator and screw-nut pair (Fig.2.).

Module characteristics:

- integrated in to DC motor gearbox output shaft one turn move nut (nut is “fixed” to prevent turning with screw) by 1,5 mm (metrics M10x1.5 screw),
- mirror inclination range against vertical or 90 degrees are ±22 degrees. These values correspond to ~±353 screw turns or ~530 mm nut movement over screw,
- angle change in range 90 ±22 degrees take ~77 seconds.

Actuator (Fig.3.) include:

- 12 V, DC motor with integrated gearbox, 550 RPM output shaft rotation speed,
- DC motor control H-bridge integrated circuit (IC TLE 5206-2 [4]),
- *electricimp* module (*imp*),
- optical IR output shaft turns counter,
- optical IR start position detector.
- 12 V, 4Ah battery and battery charging/command circuit.
- actuator's loads aren't equal - even low-speed wind significantly change load due to large mirror area - and restart after overload detection are included into micro-controller code. Load change aren't predictable and is a significant problem regarding to synchronous mirror's inclination change.

B. Functional diagram

Designed functional diagram (Fig.4.) solve listed above problematic questions regarding DC motor control and can be described by functional parts:

- four 4G/WiFi routers create 4 WiFi LAN’s. Number of routers are determined by number of addresses created by each router DHCP server - router can serve up to 32 WiFi LAN addresses,
  Here, each router serve 24 or 25 *imp's* WiFi connection (electromechanical mirror positioning modules),
- through cellular 4G network and following internet connection these LAN’s are connected to *electricimp* cloud through secure internet connection.

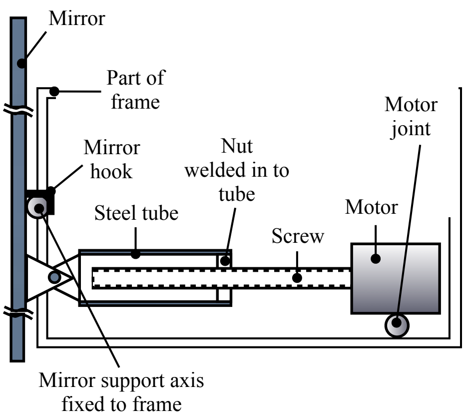

Fig.2. Mirror inclination (positioning) mechanical design

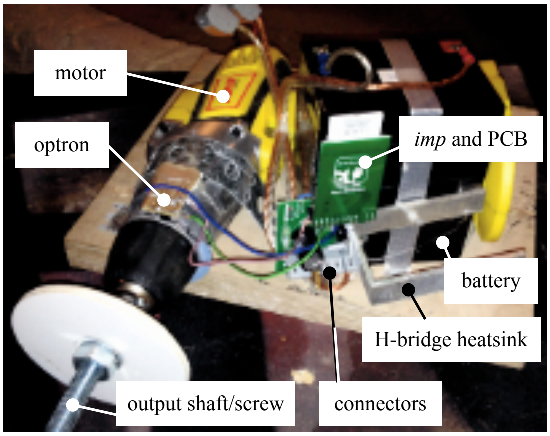

Fig.3. Electromechanical positioning module

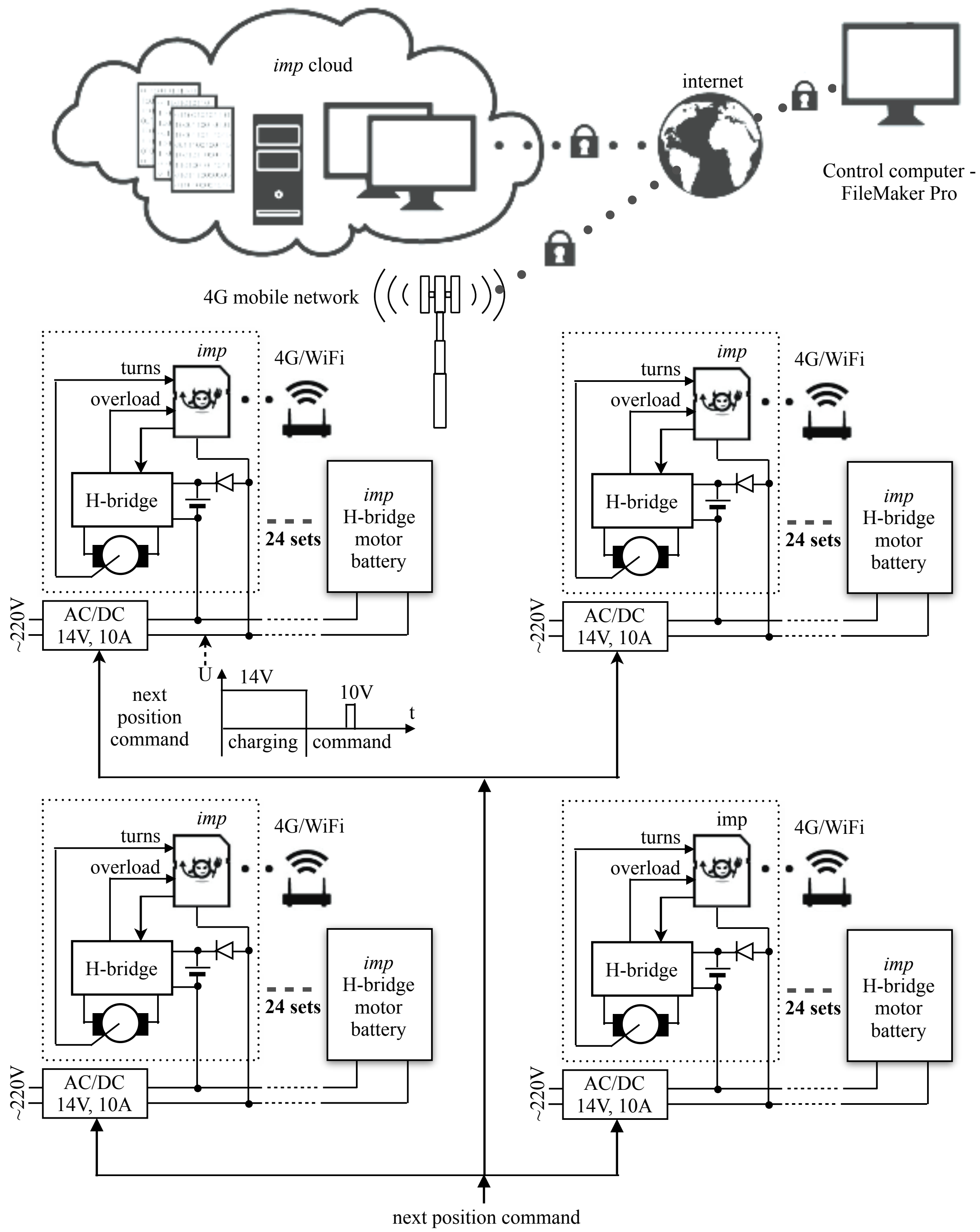

Fig.4. System functional drawing

- control computer are connected to *electricimp* cloud through internet,
- batteries are charged from AC/DC SMPS (14 V, 10 A) power supply (4 SPMS was installed) between the shows. During the show, charging is OFF.
- to change mirror inclination, 10 V, 150 ms duration, pulse are applied to the charging/command circuit, connected to *imp* by optocoupler.

III. CONTROL

Each WiFi module must be registered to known WiFi LAN (WLAN) during programming. This is time consuming task and mistakes easily can take place - each micro-controller have slightly different code due to different WLAN IP address.

Applied electric *imp* registration process allow to exclude such mistakes by way of "Blink Up" technology. To use "Blink Up", one must have *electricimp* account and know WLAN SSDI and password.

FileMaker Pro database (FM) [5] is very handy for wireless control.

FM allow to write scripts, different calculations, including text strings, create layouts, store different data , etc., as well as send out integrated in to HTTP request commands to devices through integrated web browser. *electrcimp* platform are designed to accept HTTP requests and act as necessary.

Database store all defined positions as number of screw turns for each mirror, allow edit them on the fly. Position values can be send individually to each mirror electromechanical module or sequentially to groups of mirrors by FM script, according to operator action.

FM control window screen-shoot example are shown on Fig.5.

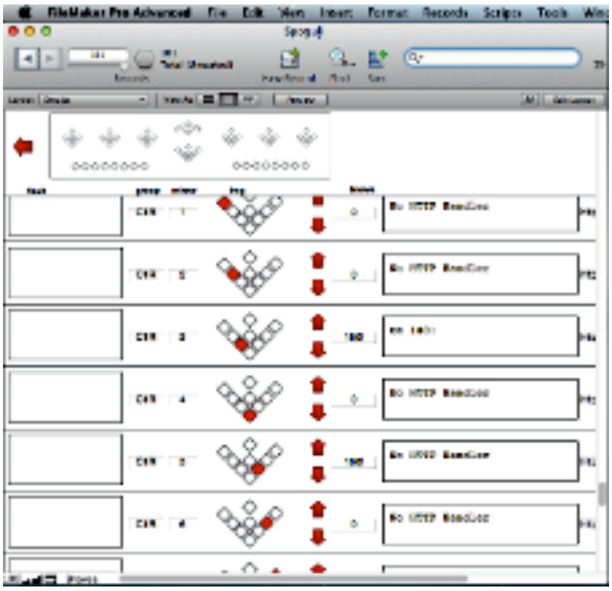

Fig.5. FileMaker Pro window to control mirrors

Received values are stored in *imp's* memory (electromechanical modules) till command pulse arrive and is detected. Operator choose moment when command pulse must be sent, according to show scenario. Here two options are available: send and store in to *imp*'s memory all values or just next following value.

Command to *imp* are formatted as text string and include each *imp* unique address generated and obtained during *imp* registration process. Text string act as HTTP POST [6] method.

IV. EXPERIMENTAL TESTS AND SYSTEM IN ACTION

Experimental tests are provided to find out optimal values in real conditions:

- data receiving delay - the latest moment to send a new inclination value before command signal occurs,
- optimal PWM frequency - low frequency cause H-bridge turning OFF, high - increase power losses,
- optimal DC motor lowest PWM value for motor start - lower value slow down performance, higher value force to turn OFF H-bridge due to over-current,
- optimal number of turns before stop to start breaking.

Testing results are:

- max delay time between command send from FileMaker Pro and receive on the *imp* are about 1500 - 2000 ms,
- optimal PWM frequency for installed DC motors are 7000 - 8000 Hz,
- PWM optimal start value is 0.55,
- PWM increase step value is 0.05 - after each screw turn PWM value increase by 0.05 till PWM value is 1.0,
- breaking must start 5-7 turns before stop by decreasing PWM value from 1.0 to 0.55 by 0.1 value step after each turn (wind speed is less than 1 m/s).
- correct stop to position is important - position are determined against start (zero) value. If, for example, first position is 100 turns and second position is 60 turns, screw rotate clockwise 100 turns and then 40 turns in opposite direction to achieve second position - 60 turns against "zero".

Constants set in initial *imp* code are wirelessly updated according to test results.

imp API code are written in Squirrel language [6], C-like programming language.

V. CONCLUSION

electricimp platform today is the easiest way to implement remote control and data logging for electro-technological devices, compared to other WiFi or ZigBee platforms, perform better "value for money", according to authors experience.

A separate synchronization network - wired or fast wireless - is necessary to electromechanical synchronous action, due to serial data transfer and communication complexity (protocol, data amount, wireless security , etc.). Fast UART RxTx 433/868 MHz transceivers are suitable for mentioned synchronization task: transmission-receiving delay is 35-40 milliseconds, according to provided tests.

Developed system implement some aspects of Internet of Things Architecture (IoT) [7] and more attention to some aspects of standardization will be included in to future development.

System - *imp* + 4G/Wifi router - can be applied to other tasks, like:

- long street LED luminaries control,
- education laboratory equipment control through internet,
- home applications,
- smart energy metering and management, etc.

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