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An Investigation of the Direct Current Motor Power Requirements for Manikin Smart Irrigation Systems

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Abstract

Manikin Irrigation Area (I.A) covers 3000 hectares and uses water from the Tefmo Dam to distribute to the Primary-Secondary-Tertiary channels, which are regulated by lift-operated watergates. Because of the unequal distribution, this process has caused rivalry and squabbles within farmer groups, eventually reducing crop yield. The evolution of microcontroller technology transformed the Watergate concept into an automated system based on certain parameters and algorithms. One such project is Manikin I.A's smart irrigation system based on Arduino, which controls water to land depending on the time from the Real-Time Clock sensor and employs a Direct Current (DC) motor as a driver to watergate. While it may function, the system has not taken into account the power requirements of the DC motor when the water runs at maximum discharge and pressure influencing the motor. The power demand of an optimum DC motor for smart watergate in 5 open channels in Manikin I.A. is investigated in this work. A total load measurement is done based on the open channel standard characteristics when the water provided speed (V) and pressure (p) are converted to energy. According to the research, a watergate control on 5 distinct open channels in Manikin I.A with 0.30 m3/s maximum water discharge and 7.56 m/s2 flow rate needs a DC motor with 35 to 43 Watt power (39,4 Watt average power) or 3 to 3.5 Ampere current (3,26 Ampere average Current) to run 24 hours.

Keywords: *open channel, DC motor, manikin irrigation area, , Arduino, smart irrigation*

INTRODUCTION

Manikin Irrigation Area (I.A) is one of 3000 ha agricultural regions in Kupang, East Nusa Tenggara Province [1, 2]. Manikin I.A management uses water from the Tefmo Dam, which has a 298 liters/second water flow [3], as well as other irrigation regions that theoretically use water from dams, ponds, checks, or other groundwater as an irrigation supply of the farm [4–6]. Water is sent to the irrigation area by primary-secondary-tertiary open channels [7], and it is regulated via watergates at each meeting channel in accordance with irrigation regulations established by the Indonesian Ministry of Public Works [8, 9].

In general, the Watergate in the channels is still operated traditionally by being raised, relocated, or rotated, depending on the Watergate concept and farmer involvement [10]. However, studies in certain areas demonstrate that there are disparities in performance between the irrigation idea and execution [11], as in Manikin I.A, which sometimes leads to jealously and quarrels among farmers owing to unequal water allocation and diminishing yields [12–14].

Many traditional mechanical systems have been transformed into automated systems based on specific parameters and algorithms in the form of application programming as a consequence of the advancement of microcontroller technology, sensors, and controllers [15, 16]. Some examples are the irrigation water gate created with Arduino for Manikin I.A [17] and the Smart Home Garden Irrigation System. Using Raspberry Pi, decrease physical human interface, operate the solenoid valve based on human needs, and provide alerts to the user for routine or critical operations. [18],

Automatic door system that employs a unique wireless ID through infrared ray or Bluetooth technology and Evaluation of a DC Servo Motor in Sliding Mode Control Approach, but does not consider how much power is optimal [19, 20], other smart development module for practicum activity [21], and Digital Pattern Approach to the Design of an Automotive Power Window Using Object-Oriented Modeling, which uses only a DC motor without considering the optimal power required for an object being driven [22]. The mechanical and control components of the smart watergate system designed for Manikin I.A. Mechanical components include steel door frames and door plates driven by DC motors. While the control section comprises of Arduino as a central processing unit and Real-Time Clock (RTC) sensors that conduct client-server data transfer [23]. Using the scheduling approach in a queue data system, the RTC communicates data time in the form of voltage to the microcontroller [24]. While Arduino serves as a server, processing data and making suggestions to other devices.

The usage of DC motors in this system is less efficient since they rapidly produce heat after a period of operation, thus they are not optimally employed for a long time. The size and characteristics of channel and Watergate have been approved in the irrigation system recommendations in Indonesia. When converted to an automated system, however, the study and selection of a DC motor as a driver must be taken into account so that the operation of smart irrigation systems becomes more optimal with the availability of DC motor, whereas the speed of the DC motor and other parameters affect the performance of the smart irrigation system [25, 26].

Some factors are considered while standardising open channel diameters, such as maximum load, friction coefficient, and channel pressure. The power can drive a force of 400 N through handlebar-operated doors. If the door has two handlebars, each handlebar must be estimated to take two-thirds of the maximum permissible weight. To prevent door jams while moving, the height and breadth of the Watergate should be less than the friction coefficient (f) between the side of the door and the pointing groove (h/bf) [27].

The friction coefficient of Watergate materials varies depending on whether the substance is iron, steel, or wood, and whether it is dry, wet, or lubricated. When the Watergate is utilised, all of this has an impact on the computation of the driving load. For the operating efficiency of the Watergate irrigation, it is suggested that the friction coefficient of different components be increased by 40-50 percent. The impact of DC motor power drives compatible with microcontrollers is the ultimate standardisation of smart irrigation systems. (1) is used to compute the total load of all items lifted by a DC motor.

Gtot=G(plate)+G(steel groove)+G(steel elbow)+G(handlebar)+P(swipe of watergate) (1)

The weight of the Watergate irrigation is determined by the weight of the Watergate plate, the weight of the groove steel, the weight of the elbow steel, and the weight of the handlebar, as indicated in (1). These four parts are linked and will be hoisted by a direct current motor. When the water runs at a specific pace [28, 29], the water pressure on the Watergate causes friction between the door plate and the frame, affecting the motor's lifting capability [30]. The estimation of DC motor power needs will be influenced by certain characteristics such as friction coefficient, water velocity, and water discharge [31]. (2) and may be used to compute the velocity of water flow and discharge of water in the channel (3).

$$V=(1/n)xR^{2/3}xS^{1/2} \quad (2)$$

$$Qmax=AxV \quad (3)$$

The quantity of water flows velocity (V) as stated in (2), with respect to the hydraulic radian, wet cross-sectional area, and slope at the irrigation channel's base [32]. While the wet cross-sectional area and the velocity of water flow influence the maximum water discharge (Qmax) in the channel, as shown in (3). A power equation based on the magnitude of lift, distance, and lift time is required to determine the DC motor power used to drive the Watergate [33]. A DC motor's total power is determined using (4).

$$W=(Fxgxh)/t \quad (4)$$

As illustrated in Figure 4, the DC motor power is directly proportional to (W) and inversely proportional to time (t). Style (F) is associated with gravity magnitudes (g) and distance (h) displacement of an item. The selection of appropriate DC motors is tied to a microcontroller-based control system, however when the system controls the Watergate on certain weight, distance, and lift, the power specification must be taken into mind.

RESEARCH METHODOLOGY

This research investigates the DC motor power requirements of watergate irrigation mounted on Tertiary channels by taking into account the weight of the load under dry channel circumstances or in the presence of water flow. This study is being completed in stages, including calculating the velocity of water flow in each channel, calculating the weight of the Watergate without water pressure, calculating the strength of the water pressure passing through each Watergate, and calculating the friction generated to the Watergate plate when the maximum flow and water pressure occurs. The last step is calculating the overall load that the DC motor is

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responsible for and converting it to energy to achieve the total power necessary. All of these steps will be considered for the gates in five tertiary open channels. Figure 1 depicts the research steps schematically.

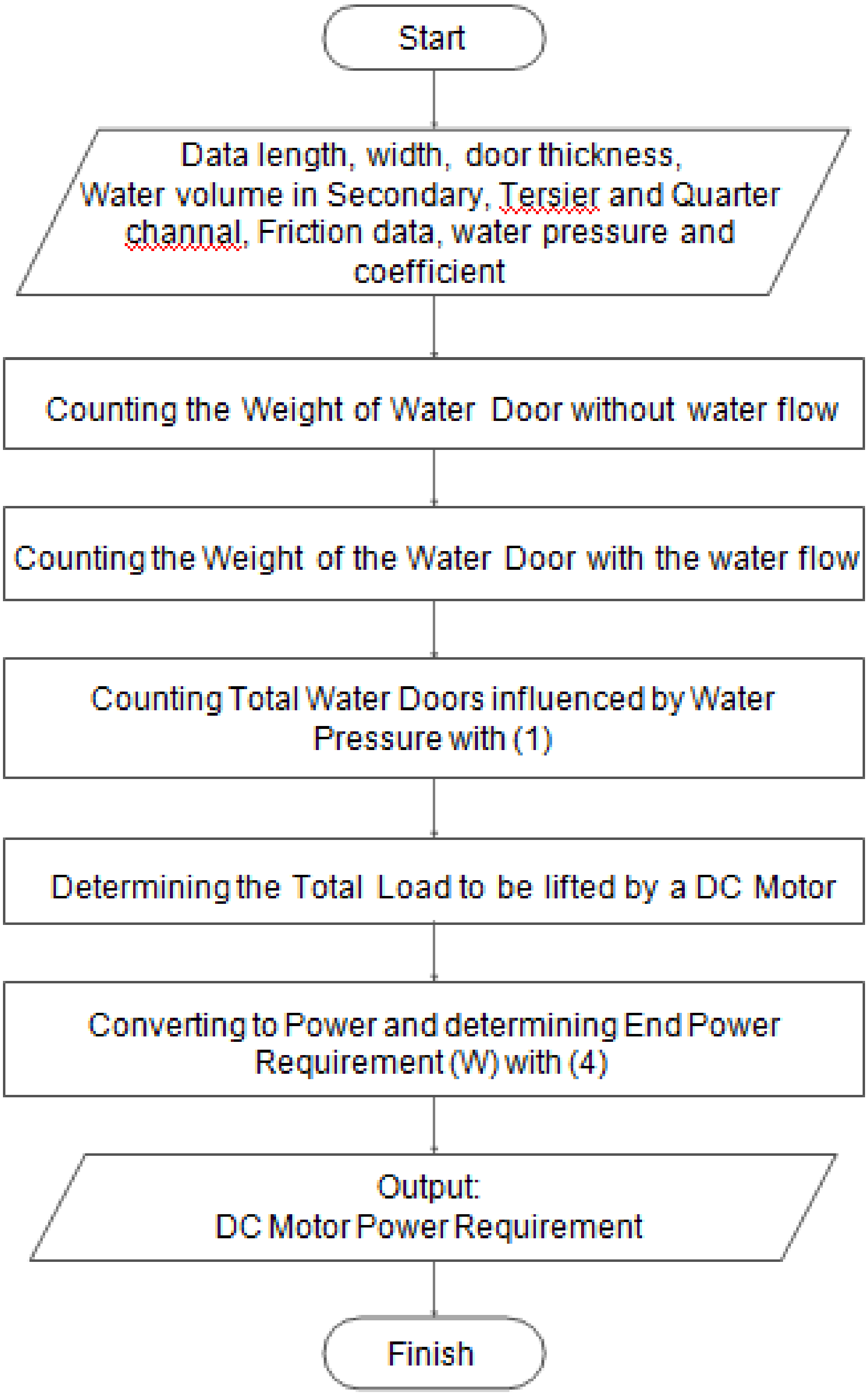


Figure 1. Phase study of DC motor power requirement on the smart irrigation system

Figure 1 depicts the processes in the evaluation of DC motor power requirements before recommending smart irrigation systems. The study starts with the collection of channel data and the Watergate parameter in accordance with irrigation system rules, as well as measurement findings at 5 open channels in Manikin I.A. The Watergate's weight and volume are measured to obtain data. The second set of data is obtained by measuring the lifting power at a certain speed and pressure that results in the greatest friction at the Watergate plate. The final step involves determining the total load from the Watergate when there is no flow and when there is maximum flow. Total load may be calculated using the (1). To acquire the correct DC motor specification for usage in Arduino smart irrigation systems, the total load value is converted to a power amount using (4) (W=(Fxgxh)/t).

ANALYSIS AND RESULTS

A smart irrigation system with a DC motor as a driver is directed to Manikin I.A, which has five open tertiary channels of various diameters. Figure 2 depicts the specification of one of the channels.

The secondary channel design A0 to two smaller channels (Tertiary) A0B0 and A0B1 are shown on the left side of Figure 2 with black lines as thick as a barrier to a tertiary channel (Watergate).

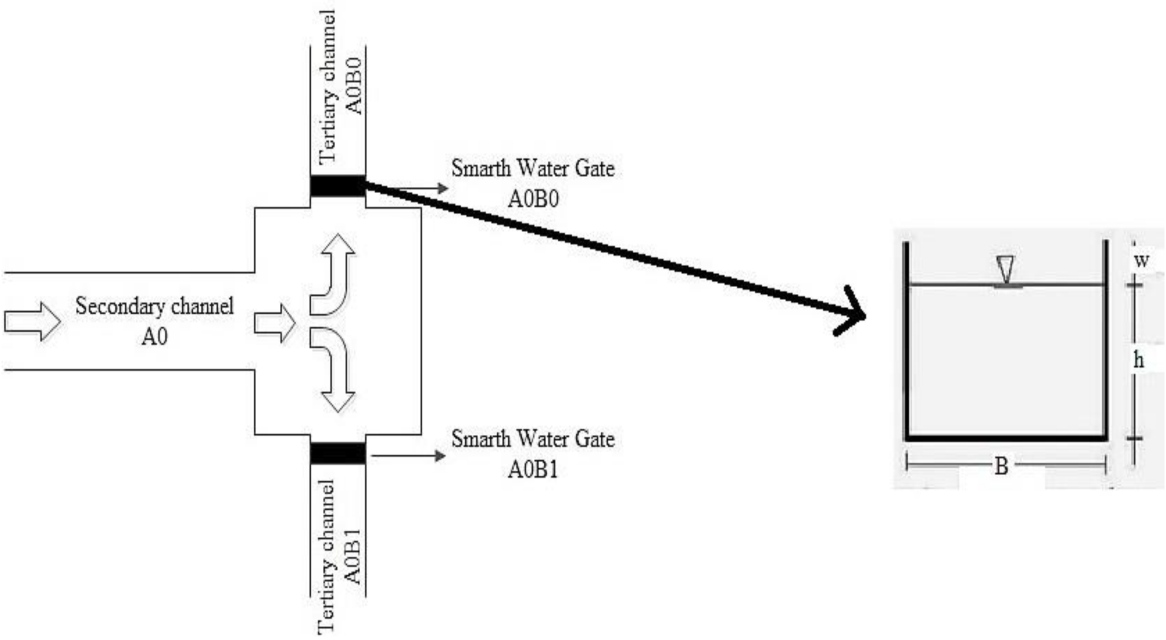


Figure 2. The open channel scheme that implements arduino smart irrigation system

Before separating into smaller channels, there is a bigger rectangular region to store water. The barrier will be replaced with an Arduino-controlled smart watering system powered by a DC motor. Figure 2's right side depicts a model and the size of smaller channels, with bottom width channel (B) indication, height water flow (h), wavelength (w), and other indications as standard parameters. The width of the preceding channel influences the size of the tertiary channels. Figure 3 depicts the measurement findings of a single tertiary channel with a width of 0.5 m and a height of 0.85 m.

The tertiary channel shown in Figure 3 has 0.50 metres of floor (B), 0.45 metres of water height (h), and 0.40 metres of wavelength (w). With a baseline slope of 0.015 Table 1 shows how the water velocity is calculated using (S) and 0.01 manning coefficient (n).

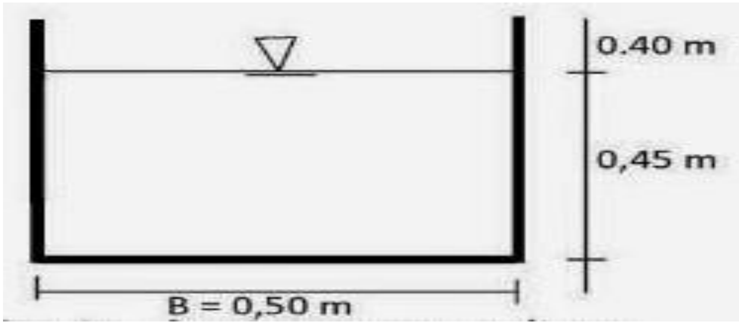


Figure 3. One of the open channels (Tertiary) in Manikin I.A

Table 1. Calculation of Tertiary Channel Parameters with 0.5 m Width of Floor Channel's (B)

Wide channel (A)	A=B x h=0.50x0.45	0.225 m^2
Circumferential channel (K)	K=B x 2h=0.50x2(0.45)	0.45 m
Hydrolis Radius (R)	R=A/P=0.225/0.45	0.5 m
Water speed (V)	$V=(1/n)\ xR^{2/3}xS^{1/2}$ $=(1/0.01)\ x\ (0.5)^{2/3}x(0.015)^{1/2}$ =100 x 0.63x0.12	7.56 m/s
Maximum discharge (Qmax)	Qmax=A x V=0.225x7.56	1.70 m^3/s
Water pressure (P)	P=ρxgxh $=997{,}2\ kg/m^3 x9{,}81\ m/s^2 x0{,}45\ m$	4402,1 p

Table 1 shows the calculation of Tertiary channel characteristics with a B of 0.50 m, resulting in a water flow rate of 7.56 m/s. The discharge of water that may travel through a 0.50 metre open channel at this velocity is 1.70 m3/s.

The water discharge at that pace always applied 4487.4 Pascal pressure to the Watergate plate, causing friction between the plate and the Watergate frame. When powered by a DC motor, this friction acts as an additional load (weight) on the Watergate. Table 2 shows the whole size of the flow rate at 5 tertiary channels in Manikin I.A.

Table 2 depicts the velocity of water flowing through five tertiary channels in Manikin I.A, each with a distinct bottom width and pressure. The flow velocity and maximum water flow in all channels are almost same (approximately). The average water discharge is 1.69 m3/s and the average water flow velocity is 7.56 m/s in all channels. The discharge and velocity give distinct benefits.

When powered by a DC motor, pressure on the Watergate might change its weight. Figure 4 depicts a Watergate that will be installed on the open channel of the Manikin. The Watergate is built of steel and has a handlebar and a gear that is linked to a DC motor. Watergate's plate is bordered on both sides and top by elbow steel.

Table 2 Water Flow Velocity at 5 Tertiary Channels in Manikin I.A

No	channels size				Parameters		
		A (m^2)	K (m)	R (m)	V (m/s)	Qmax (m^3/s)	P (pascal)
1	B=0,40 m, h=0,56 m	0,224	0,45	0,5	7,56	1,69	5478,2
2	B=0,50 m, h=0,45 m	0,225	0,45	0,5	7,56	1,70	4487,4
3	B=0,60 m, h=0,37 m	0,222	0,44	0,5	7,56	1,68	3619,5
4	B=0,70 m, h=0,32 m	0,224	0,45	0,5	7,56	1,69	3130,4
5	B=0,80 m, h=0,28 m	0,224	0,45	0,5	7,56	1,69	2739,1

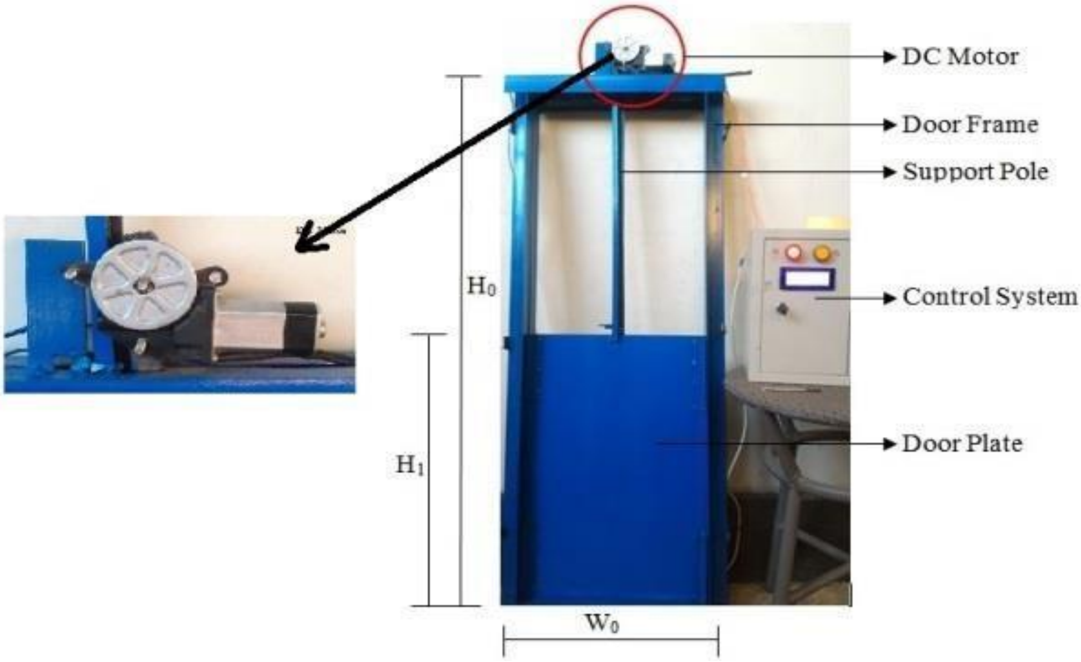


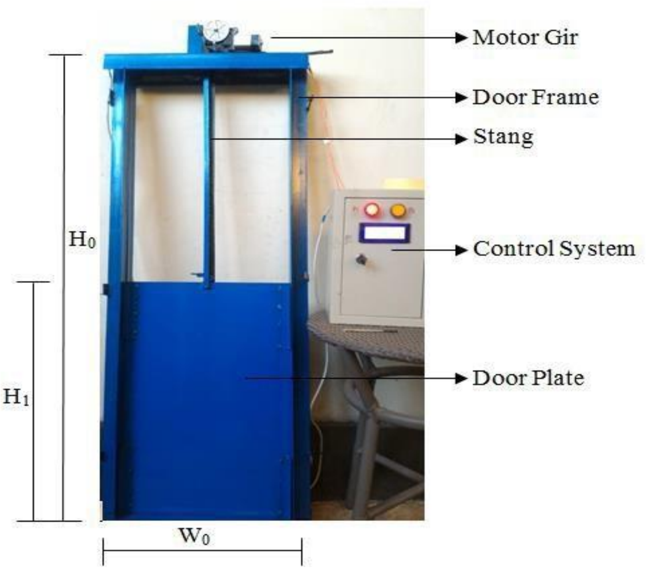
Figure 4. Watergate for Manikin I.A

When the channel is full with water, the maximum capacity of a DC motor is estimated. The plate of Watergate, handlebars, steel gear, and elbow steel on the frame are the four essential components that determine the operation of the Arduino smart irrigation system. When there is a specific speed and discharge of water, the friction between the plate and the frame becomes an additional parameter that impacts the lift capabilities of the DC motor. Based on Table 2, the weight of the Watergate is examined in two situations, namely when the channel is empty and when it is full. The door weight is a hefty accumulation of four basic components when the channel is empty. The weight of each component measured in the empty channel was 2.75 kg+1.75 kg+5.25 kg+2.75 kg+0.75 kg=13.00 kg=13.00x9,8=127,4 Newton.

This indicates that the door weight for the 0.5 metre wide channel is 127.4 Newton when it is empty. However, the weight within the drains is modified by the pressure received, friction between the door plate and frame, and water density. Table 3 shows the estimates for a 0.5 metre wide channel.

Table 3. The Lifting Load of Doors at 0.5 m Width and 7.56 m/s of Flow Rate

Specification	Value
The weight of steel groove : W0=1 x 3,00 x 0,50 x 10	15 N
Weight of door plate: W1=0,56 x 0,45 x 0.005 x 7,8 x 10^4	98,28 N
Weight of elbow steel : W2=2 x 1,50 x 0,30 x 10	9 N 1,5 N
Weight of handlebar: W4=0,70 x ¼ x 0,030 x 7,8 x 10^4j	40,95 N
The weight of Watergate (G) :	164,73 N
Maximum Weight Maximum with pressure: H=1/2(0,50 + 0,45) x 1,70 x 7,56 x 8,9 x 10^4	514722,6 N
friction force: Wg=f x H=0,3 x 16159,5	154416,78 N
Lift and Press force: Wg ± G=154416,78 + 164,74 154416,78 - 164,74	154581,52 N 154252,04 N

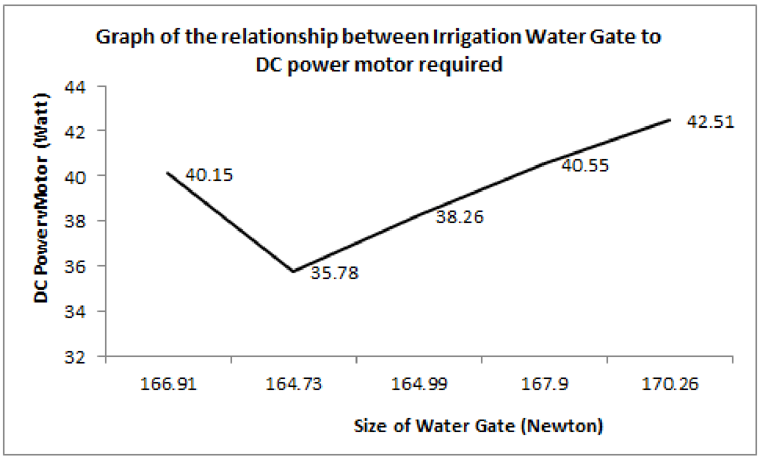


Figure

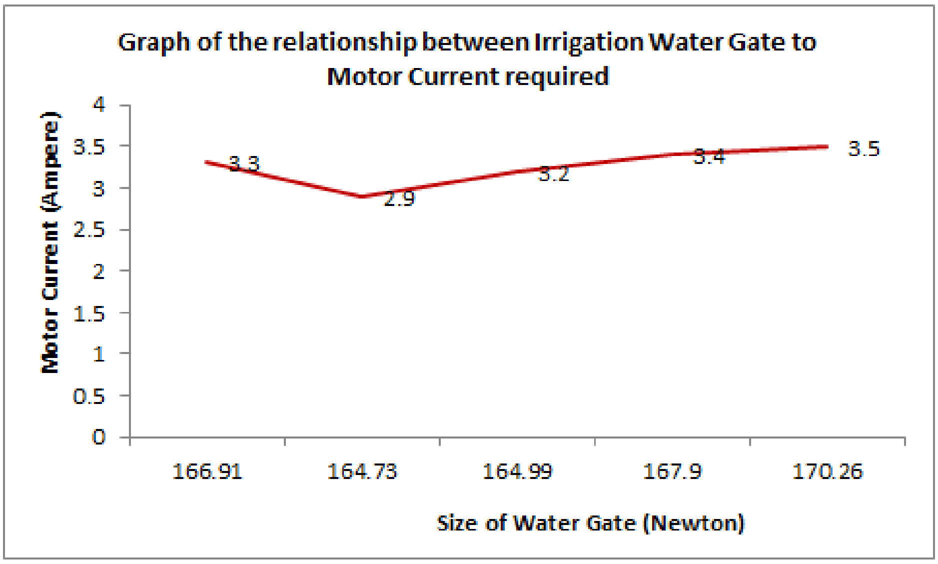
According to Table 3, the weight of the Watergate that influences water pressure is 154581.52 N, which means that when the 0.5 metres channel has water, the flow rate is 7.56 m/s and there is a maximum load of 154581.52 N that must be driven by a DC motor as far as 0.6 metres, requiring an energy of 154581.52/0.6 meters=257635,867 Joule. (Wxh)/t=257635,867/7200 s=35.78 Watt is the power to be provided for a DC motor. If the system is powered by a 12 Volt DC motor, the current capacity is 35.78/12= 3 Ampere. Table 4 summarises the lifting load calculation of 5 open channels (tertiary) in Manikin I.A.

Table 4. Lifting Load Calculation on 5 Open Channel in Manikin I.A

Watergate size				Parameters		
	G (N)	H (N)	Wg (N)	Wg±G (N)	Power (Watt)	Current (A)
0,40 x 0,56	166,91	577633,14	173289,94	173456,86 | 173123,03	40,15	3,3
0,50 x 0,45	164,73	514722,60	154416,78	154581,52 | 154252,04	35,78	2,9
0,60 x 0,37	164,99	550353,75	165106,13	165271,12 | 164941,14	38,26	3,2
0,70 x 0,32	167,90	583352,28	175005,68	175173,58 | 174837,78	40,55	3,4
0,80 x 0,28	170,26	612765,00	183829,50	183999,26 | 183659,24	42,51	3,5



(a)



(b)

Figure 5. Watergate weight relationship with dc power, and current (a) watergate weight and dc power (b) watergate weight and current

Table 4 shows how to calculate the DC motor power required for the Watergate in 5 tertiary channels in Manikin I.A. Each channel (based on the size of the Watergate) contains the entire weight of the gate (G), the weight with the effect of water pressure (H), and the accumulated load due to friction between the plate and the door frame. The load accumulation (weight of gate and friction) is then translated to energy (Power), with the result being gate 1 needs 40.15 Watt, gate 2 requires 35.78 Watt, gate 3 requires 38.26 Watt, and gate 4 requires 40.15 Watt.

Gate 4 necessitates 40.55 Watt, whereas gate 5 necessitates 42.51 Watt. Because the system needs a DC voltage of 12 volts, each DC motor receives optimal current that can operate on the DC motor circuit. Figure 5 depicts the result of Table 4 as a graph showing the connection between the weight of the door and the DC motor power (a). The DC motor power needed for the larger Watergate is higher, ranging from 35.7 Volts on the second gate to 42, 51 Watts on the fifth gate. Figure 5 (b) depicts the relationship between the Watergate's weight and the current on the DC motor circuit. The current needed for the DC motor circuits increases with the width of the Watergate, from 3.5 Ampere in the second DC motor circuit to 3.5 Ampere in the fifth door DC motor circuit. The average DC power need of Arduino smart irrigation systems in the open 5 channels of Manikin I.A is 39.45 Watt, with an average current of 3.26 Ampere to move the Watergate as far as 0.6 metres in one operation during 24 hours.

CONCLUSION

The development of the Arduino smart irrigation system in Manikin I.A for 5 open channels (tertiary) necessitates the use of a DC motor to operate the watergate when it opens and closes automatically. The investigation of the DC motor power required on 5 smart watergates yields power ranging from 35 to 43 Watt, or an average of 39.4 Watt. If the circuit voltage is 12 volts, the electric average current in a DC motor is 39.4/12=3.26 amps. Electrical power necessary to raise the Watergate 0.6 metres in 24 hours, lifting 2 hours (7200 seconds) in one phase. According to the size examined, this power value achieved is the optimal value for each gate built on an open channel. Power demand estimates on Arduino smart irrigation systems may be applied to additional open channels (secondary, primary, tertiary, and quarter) in any irrigation area.

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