



MONITORING AND CONTROLLING FUEL LEVEL OF REMOTE TANKS USING APLICOM 12 GSM MODULE

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ABSTRACT

This paper basically describes how fuel level in fuel tanks can remotely be controlled and monitored in order to provide a cost-effective solution to a unique challenge of fuel shortage. This was experimented with the aid of Aplicom 12 GSM Module connected to a fuel gauge of a remote tank and the variation in fuel level was remotely monitored through a compatible mobile phone. Aplicom 12 Configurator software was used to configure the Aplicom 12 GSM Module. Then, control messages were sent from a compatible mobile phone through a GSM network to the Module and response messages were sent back to the mobile phone in form of different voltage levels which correspond to the volumes of fuel in the remote tank. An equation and a graph that relates volume to voltage were established.

Keywords: fuel level, remote fuel tanks, monitor, control, aplicom 12 GSM module, mobile phone.

INTRODUCTION

Remote sites fuel tanks pose a great challenge to organizations due fuel shortage as a result of threats such as fuel leakage, fuel theft, premature dry-out, inaccurate refilling and improper engine fuel consumption. In order to cater for these problems, GSM based wireless communication is used to provide a global and cost-effective solution for wide-area monitoring.

Means of linking the fuel level in the tank to Aplicom 12 GSM Module over an analogue IO pins are provided at each site. Then, a reliable communication is established between a mobile phone and the Aplicom 12 GSM Module over a GSM network, so that the status of the fuel in the tank can remotely be monitored by the mobile phone subscriber on a regular basis.

OVERALL SYSTEM ARCHITECTURE

Aplicom 12 GSM Module provides Machine-to-Machine (M2M) connectivity between a mobile phone within an intranet and a remote device such as fuel gauge as it is shown in Figure-1 below.

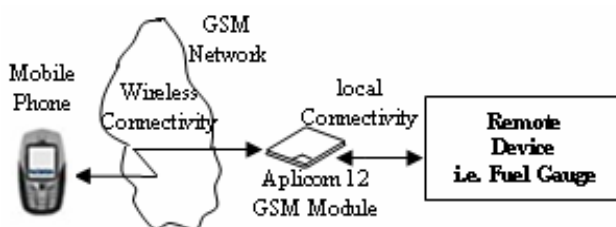


Figure-1. Overall system architecture.

Local connectivity is meant to manage the component of the remote device and this connected was achieved by connecting the fuel gauge to the IO control pins of the Apilcom 12 GSM Module.

Wireless connectivity was established between the Aplicom 12 GSM Module and the mobile phone over a GSM network. A message sent from mobile phone was

transmitted over a GSM network to the Module at the remote site and a response message (indicating the status of the fuel in the tank) was sent back to the originator (i.e., the mobile phone).

CONTROLLING AND MONITORING METHOD

Aplicom 12 Configurator software was used to configure the Aplicom 12 GSM Module before this module could receive a control message from a mobile phone and then control the fuel gauge attached to it. The Module, an MTN SIM and an antenna were mounted on an Aplicom test board. A fuel gauge was connected to input pin header 2 on the side of the test board, the PC (with already installed configurator software) was connected to the test board using a data cable, communication switch and RS-232 switch were turned ON and lastly, power supply was connected to the test board and to an AC wall outlet. The experimental setup is shown in Figure-2.

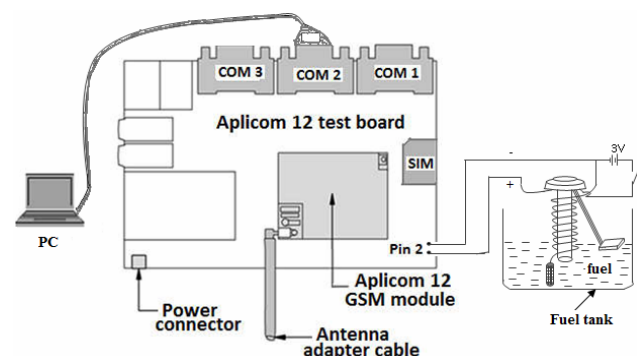


Figure-2. Experiment setup.

After completing the above setup, the configurator automatically established a connection between the PC and the Aplicom 12 Module when the configurator was started. This is shown (as it is seen on PC monitor) in Figure-3 below. It should be noted that the PC



was disconnected after the configurator has established a connection.

incoming control messages to get into the Module and perform their fulfilling purposes.

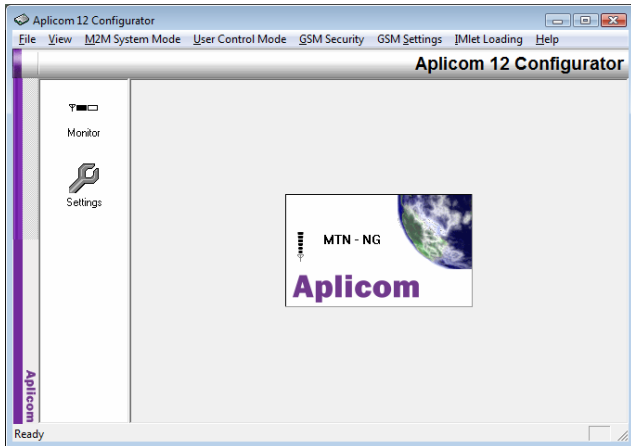


Figure-3. Configurator start-up dialog box.

Since Message identifier of 1 - 8 characters must be configured in order to use the user control mode, “test123” was used as a message identifier, and then “change” and “write parameter” buttons were clicked to effect the change. Figure-4 shows the dialog (*User Control Mode->Settings->Initialize*) that was used to configure the message identifier.

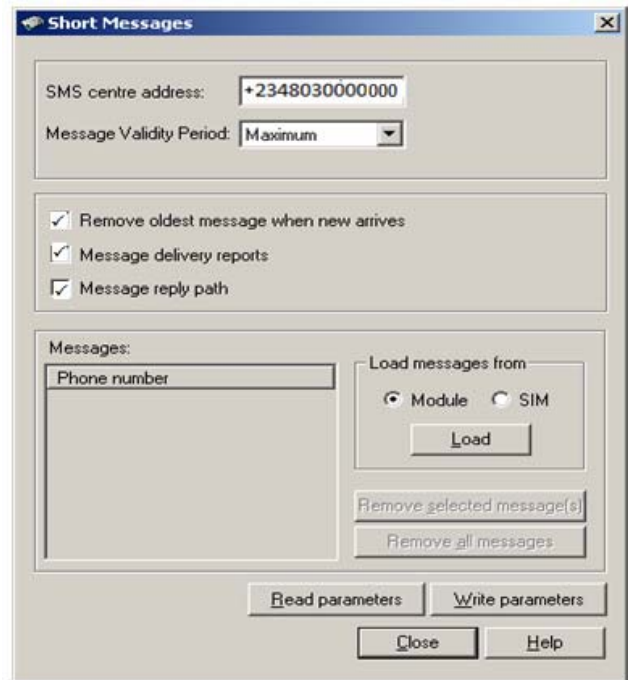


Figure-5. Short message dialog box.

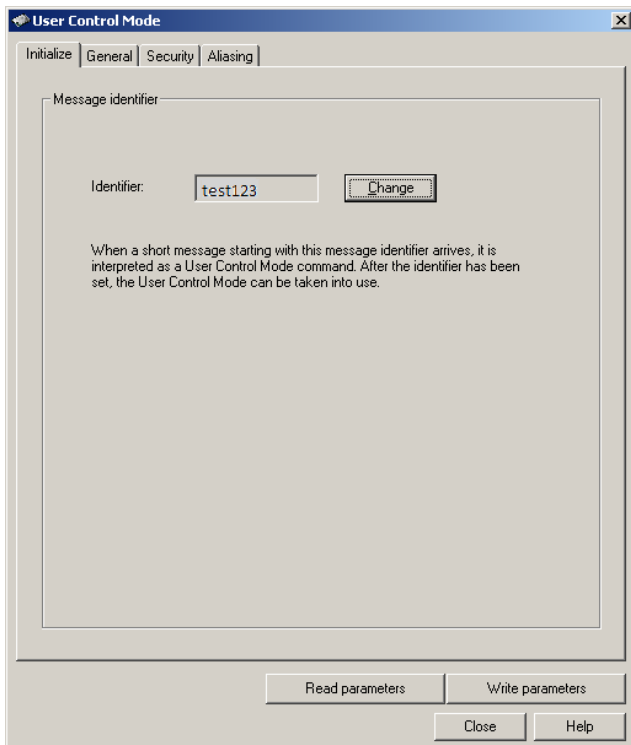


Figure-4. User control mode dialog box.

SMS centre address +234803000000 was set using the dialog (*GSM Settings->Advanced->Short Messages*) shown in Figure-5. “Remove oldest message when new arrives” option was activated so as to allow the

Security setting was enabled on the Module in order to deny unauthorized users from getting access to the Module. Figure-6 shows a dialog (*User Control Mode -> Settings -> Security*) where security setting was configured with Aplicom 12 configurator.

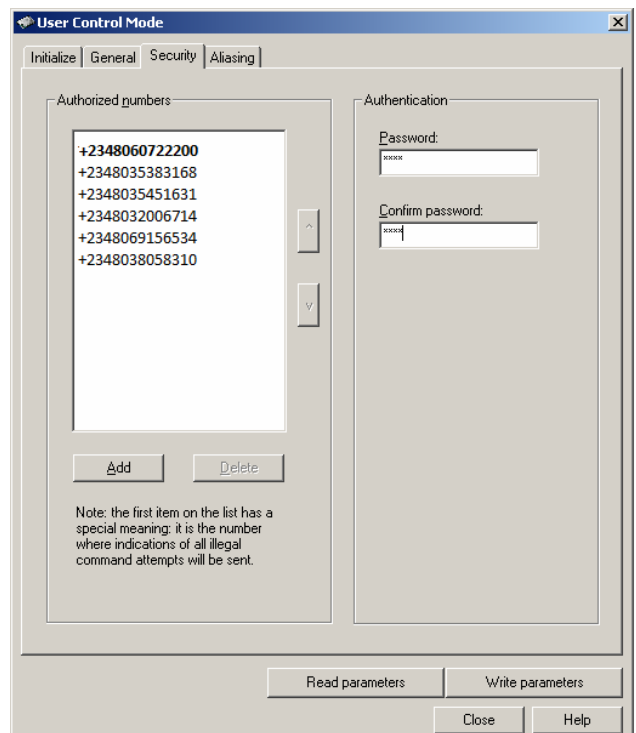


Figure-6. Security setting dialog box.



As shown in Figure-6, authentication (which is a user-specified password) was used to secure communication between a mobile phone and the Module. Authorized numbers as shown above are the only numbers that were allowed to send control messages and get replies from the Module. The first number in bold (+2348060722200) is the number of the main user and this number was notified of unauthorized control attempt into the Module.

Input setting was configured using the dialog (File->Module Configuration->Input Settings) as shown in Figure-7.

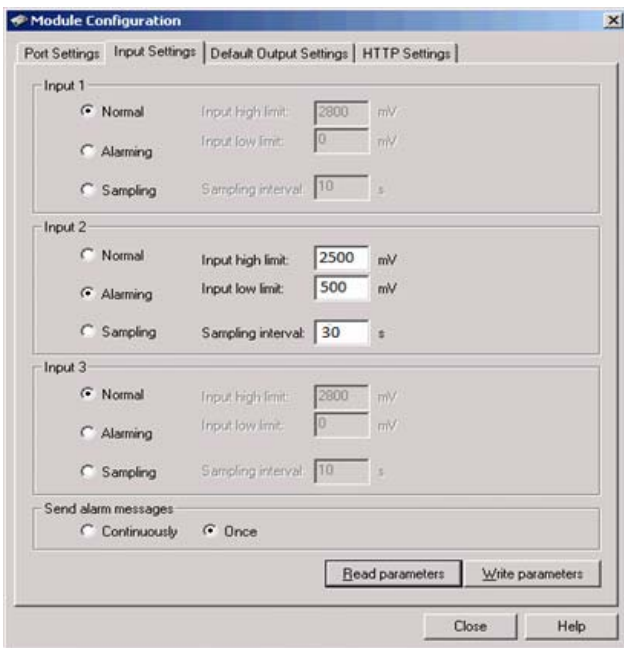


Figure-7. Input setting dialog box.

Since the maximum voltage that the can send as a response message is 2800 mV, high alarm limit of 2500 mV and low alarm limit of 500 mV were set to the analogue input pin 2. The analogue input pin was selected because the variation of fuel level in the tank is continuous in nature. Input sampling interval was set to 30 seconds so that the module could check the fuel level every at 30 seconds interval. To reduce the amount of alarm messages hence, amount of communication over a GSM network, "Once" option was selected. Alarms were only sent to the mobile phone when either high limit or low limit was crossed.

To query the status of the analogue input pin 2 (which is directly connected to the fuel gauge), the fuel in the remote fuel tank was varied between 1 and 10 litres and control message was sent from the mobile phone, over a GSM network, to the Module and a status message was instantly sent back to the phone as it is shown below

Control message: *test123 Input_Get 2*

Response: *Input 2: 1750mV*

Alarm subscription was achieved using the command below and a response message was received by the mobile phone as shown below.

Control message: *test123 Input_Get_Change 2*

Response: *OK*

After the alarm subscription, the fuel in the tank was drained, and the alarm limit was crossed then, a status message was sent to the subscriber mobile phone as it is shown below

Response: *Input 2: 100mV*

DATA ANALYSIS

Readings were taken three times from the fuel tank and the average values were considered so as to ensure accuracy. Table-1 shows the results obtained during the experiment.

Table-1. Determination of relationship between voltage and volume.

Volume, u (litres)	Average voltage $V = \frac{V_1 + V_2 + V_3}{3}$	u^2	Vu
10	2615	100	26150
9	2366	81	21294
8	2140	64	17120
7	1999	49	13993
6	1702	36	10212
5	1480	25	7400
4	1261	16	5044
3	1045	9	3155
2	830	4	1660
1	600	1	600
$\Sigma u = 55$	$\Sigma V = 9748$	$\Sigma u^2 = 384$	$\Sigma Vu = 60828$

Since the plot of voltage V against volume u in Table-1 will not produce a straight line graph, it is necessary to introduce regression analysis by using equation of a line given by

$$V = mu + c \tag{1}$$

Where m = gradient of a line

and c = intercept on V-axis

Regression coefficient m and c are obtained using the equations below.

$$\Sigma V = cN + m\Sigma u \tag{2}$$

$$\Sigma Vu = c\Sigma u + m\Sigma u^2 \tag{3}$$

since the Number of coordinates $N = 25$, and Σu , ΣV , Σu^2 and ΣVu have been determined in Table-1, equation (2) and (3) become

$$9748 = 10c + 55m \tag{4}$$

$$60828 = 55c + 384m \tag{5}$$



Solving equation (4) and (5) by simultaneous equation give $m \approx 226$ and $c \approx 362$. By substituting these value of c and m into equation (1), an equation which represent the regression line of voltage V on volume u is obtained, and is given as,

$$V = 226u + 362 \tag{6}$$

Equation (6) above is used to generate the first two columns of Table-2 below.

Table-2. Determination of correlation coefficient and skewness coefficient.

Volume u (litres)	Volume $V = 226u + 362$	Volume deviation $(u - \bar{u})$	Voltage deviation $(V - \bar{V})$	$(u - \bar{u})^2$	$(V - \bar{V})^2$	$(u - \bar{u})(V - \bar{V})$	$(V - \bar{V})^3$
10	2622	5	1130	25	1276900	5650	1442897000
9	2396	4	904	16	817216	3616	738763264
8	2170	3	678	9	459684	2034	311665752
7	1994	2	452	4	204304	904	92345408
6	1718	1	226	1	51076	226	11543176
5	1492	0	0	0	0	0	0
4	1266	1	226	1	51076	226	11543176
3	1040	2	452	4	204304	904	92345408
2	814	3	678	9	459684	2034	311665752
1	588	4	904	16	817216	3615	738763264
0	362	5	1130	25	1276900	5650	1442897000
$\Sigma u = 55$ $\bar{u} = \frac{\Sigma u}{N} = 5$	$\Sigma V = 16412$ $\bar{V} = \frac{\Sigma V}{N} = 1492$	$\Sigma(u - \bar{u}) = 30$	$\Sigma(V - \bar{V}) = 6780$	$\Sigma(u - \bar{u})^2 = 110$	$\Sigma(V - \bar{V})^2 = 5618360$	$\Sigma[(u - \bar{u})(V - \bar{V})] = 24858$	$\Sigma(V - \bar{V})^3 = 5194429200$

To ascertain whether the plot of volume V against volume u in Table-2 above will produce a graph with a straight line coordinates, linear correlation coefficient (hence correlation percentage) and skewness coefficient were determined as follows:

Linear correlation (or Pearson-Bravnis) coefficient r is given as

$$r = \frac{[(u - \bar{u})(V - \bar{V})]}{\sqrt{\Sigma(u - \bar{u})\Sigma(V - \bar{V})}} \tag{7}$$

It is seen from Table-2 above that the value of r will become

$$r = \frac{24858}{\sqrt{110 \times 5618360}} = 0.9999 \tag{8}$$

$$\therefore r \approx 1 \tag{9}$$

Also, correlation percentage $\approx 100\%$
Skewness Coefficient α is given as

$$\alpha = \frac{1/N \Sigma(V - \bar{V})^3}{\sigma^3} \tag{10}$$

where $N =$ number of coordinates $= 11$

$$\sigma = \text{variance} = \frac{\Sigma(V - \bar{V})^2}{N} \tag{11}$$

It is seen from Table-2 above that the variance σ will become

$$\sigma = \frac{5618360}{11} = 510760 \tag{12}$$

and skewness coefficient α becomes

$$\alpha = \frac{1/11 \times 5194429200}{510760^3} = 0.000000003544 \tag{13}$$

$$\therefore \alpha \approx 0 \tag{14}$$

It is seen that $r \approx 1$ which shows a good agreement between input (i.e. the volume) and the output

(i.e. the voltage). Also $\alpha \approx 0$ shows that error is spread

evenly and plot of voltage against volume, from Table-2, gives a straight line graph as it is shown below.

SUMMARY OF MEASURED DATA

It is seen that there were slight variation in the measured data with respect to time. These variations are as a result of environmental factors such as change in pressure on the surface of the fuel in the tank and change



in temperature which might have caused slight expansion or contraction of the fuel tank. Due to these factors, the plot of voltage against volume could not produce a straight line graph. Therefore, regression analysis was used to generate a straight line graph (Figure-8) which represents an expected plot of voltage against volume under normal environmental conditions.

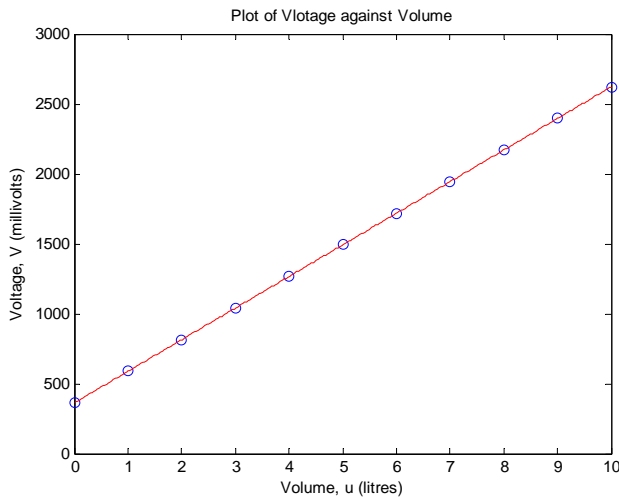


Figure-8. Plot of voltage V against volume u .

CONCLUSIONS

This paper has shown how a cost-effective solution to a great challenge of an organization, as a result of fuel shortage, can be provided. It is recommended that the Module should be powered ON always and the network from the GSM operator must always be up to ensure constant monitoring of the remote site fuel tanks.

Equation (6) and the graph in Figure-8 can be used to monitor the expected volume of fuel in the remote tank as soon as a voltage level is received by a compatible mobile phone.

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