# Automating Field Motor and Irrigation Systems for Better Crop Yield

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***Abstract*- The basic idea behind the project to is optimize the overall crop yield through systematic layout planning of field and utilizing nutrient sensor. The field is dividing into "n" grids that consist of a sensor embedded into the soil in each. Each sensor consists of a thermocouple that is connected to a LED circuit. When fertilizers and water are introduced due to the following exothermic reaction, the circuit breaks. This is denoted by a green LED light (binary 0). Counter-wise, if the nutrient reactions are not strong enough to send the voltage required to break the circuit, the LED glows red (binary 1). These signals are relayed using GSM modem and ZIGBEE protocol to the motor which consists of receiver, transmitter and relay signal processor. Then processor deploys water and nutrients required per grid according to this analysis. Water wastage and over-utilization of fertilizer is avoided, thereby increasing crop yield.**

**Keywords- Zigbee Module; three-phase Induction Motor; GSM Modulus; IGBT; Opto-Coupler**

## I. INTRODUCTION

There have not been any significant technological advancements being made in agricultural sector as compared to other sectors. Irrigation system needs to be monitored on a regular basis. The first aim of the project is to reduce the wastage by automating the entire irrigation system. The three-phase supply system is now available worldwide, except perhaps in rural areas where only single-phase supply is available.

The second aim of our project is to tackle this issue, thereby enabling the operation of these pumps even in absence of three phase supply, resulting in optimized field irrigation and better crop yield.

*Problem Statement:* The moisture content of the field is not monitored and it is manually observed by the farmers which are prone to errors.

## II. DESIGN AND IMPLEMENTATION

The technical details of the project contain block diagram, circuit connections and detailed explanation of various components used. The analysis is split in two parts:

- Automation of Irrigation system using wireless communication
- Operation of three phase motor pump using single phase supply

### Automation of Irrigation system using Wireless communication

The water or moisture sensor is placed in the field which continuously senses the moisture content in the field. The output of the sensor is transmitted wirelessly using a zigbee module. Another zigbee module at the receiving end receives these transmitted signals and gives it as an input to the main micro-controller which is the control unit. This main micro-controller is programmed to perform the various functions. First, the opening/closing of the shutters is controlled by the main microcontroller depending on the sensor output. Secondly, once all the fields are irrigated to the optimum level a signal is sent to switch off the motor thereby stopping the water supply. Thirdly, the main micro-controller sends all the details of the operations being performed in the field to the farmer's mobile using GSM. The farmer can perform the operations in the field either in manual mode or in automatic mode. In the manual mode the farmer will wirelessly control the on/off of the motor and the shutters irrespective of the sensor output. In automated mode, the operation is based on the sensor output as explained above. The picture of the hardware model of irrigation part is given below:

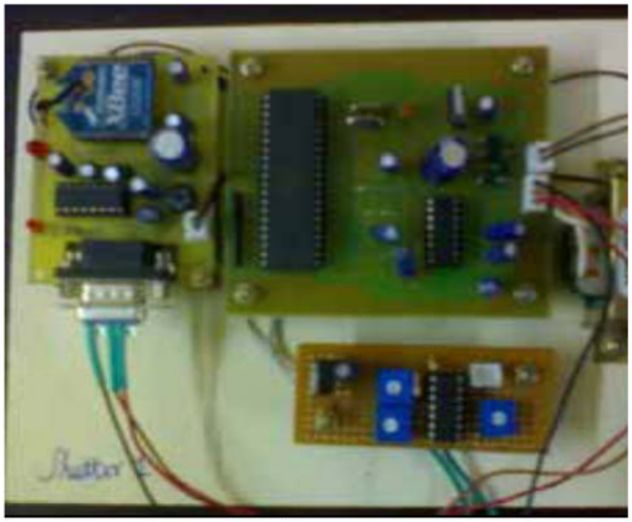
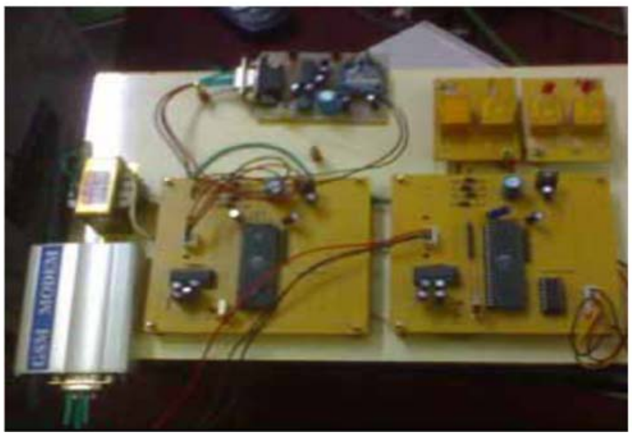


**Fig 1**



*Main control unit and GSM module*

III. OPERATION

Single-phase motors are the most common form in the lower horse-power ranges, but they become uneconomical for ratings above about 0.5kW and therefore an increasing tendency to use standard three-phase motors supplied from single-phase supply if the three-phase supply is not available.

The phase and neutral of the single phase supply are given to the two windings of the three phase induction motor. The third winding is connected to the line through a fixed and variable capacitor, both being parallel to each other. The capacitance of the variable capacitor is varied electronically with the help of an IGBT connected in series with the capacitor. The duty cycle of the IGBT is varied continuously with respect to motor speed as follows. The speed of the motor is obtained using a tachometer. The frequency pulses are tapped out from the tachometer and given to a frequency to voltage converter. The voltage level is to the comparator whose other input is the saw tooth pulse to IGBT. Hence, as the speed varies the voltage level and hence the duty cycle of the IGBT varies thereby varying the net capacitor value. This causes a continuous variation of unbalance between the three-phases of the induction motor. An opto-coupler is used in order to isolate the low voltage electronic circuit from power circuit.

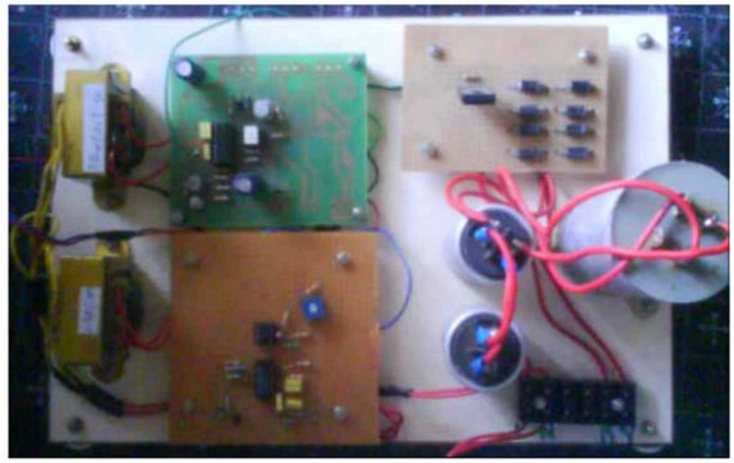


***Fig 2*** *Zigbee Reciver*

IV. TESTING

In the automation part the reference of the comparator of the moisture sensor is set to 4.54V. When the field is dry, the sensor produces a voltage of 4.81V and hence the comparator output will be high. The sensor gives an output voltage of 3.2V during wet condition and the comparator output will be at zero volts. This output is converted to serial data with the micro controller for Zigbee transmission. After Zigbee transmission, the GSM module either transmits or receives messages as per the mode of operation. The tacho generator is coupled with the motor to get the desired speed. This gives the frequency pulses as output. There is a digital tachometer connected to this which reads the motor speed. These frequency pulses obtained are spike waveforms. This output from the tacho generator is amplified and fed to the frequency to voltage converter to get appropriate voltage for corresponding speed of motor. As the pulses obtained are very less in magnitude, an amplifier circuit is used and then it is converted to voltage pulses. The output voltage thus obtained is about 2V. The output obtained from the F to V converter is fed to the inverter LM 358 so that voltage varies in direct proportion to frequency. The magnitude remains same (2V) DC voltage output got from F to V converter and inverter circuit acts as the reference and cuts the saw tooth waveform to get the PWM output. These PWM pulses are fed to the base of the IGBT and hence switching of the IGBT is controlled by the PWM output. This in turn controls the net capacitance of the circuit.

| Date (8.30 am) | Atmospheric Temperature (ºC) | Atmospheric Humidity (%) | Rainfall (mm) | Wind Speed (km/hr) | Wind Direction (degree) | Radiation (W/m2) | Soil temp. (ºC) | Soil moisture (%) |
|---|---|---|---|---|---|---|---|---|
| 3/04/14 | 31 | 61 | 0.8 | 17 | 246 | 1166 | 30 | 34 |
| 4/04/14 | 27 | 71 | 0.2 | 11 | 235 | 352 | 29 | 28 |
| 5/04/14 | 32 | 94 | 6 | 28 | 264 | 1325 | 31 | 54 |
| 6/04/14 | 28 | 93 | 0.2 | 37 | 413 | 1448 | 30 | 28 |
| 7/04/14 | 29 | 94 | 0.2 | 32 | 218 | 186 | 30 | 29 |
| 8/04/14 | 29 | 89 | 0.0 | 28 | 367 | 1553 | 30 | 14 |

***Table 1** – Recorded Data On Field*

## V. METHODS AND PROCEDURES

Quaternary ammonium compounds have successfully been used as the ligands in non-porous PVC-based nitrate ion-selective electrode membranes. The ligands -tetradodecylammonium nitrate (TDDA), and methyltridodecylammonium chloride (MTDA); and the plasticizers - tri-(2-ethylhexyl)trimellitate (TOTM), nitrophenyl octyl ether (NPOE),dibutylphthalate (DBP) and tri-(2-ethylhexyl) phosphite (TEHP) were selected for testing based on previous studies (Nielson and Hansen, 1976; Tsukada et al., 1989). Therefore, various membranes which contained either TDDA or MTDA as the ligand combined with one of the plasticizers, DBP, TOTM, NPOE or TEHP, were prepared. Disks (3.5 mm dia.) were attached to the end of a Hitachi ion-selective electrode (ISE) body. The ISE electrode was filled with a solution consisting of 0.01 M sodium chloride (NaCl) and 0.01 M sodium nitrate (NaNO3) with a silver/silver chloride internal reference wire. The ISE electrodes were conditioned in a 0.01 M potassium nitrate (KNO3) solution for at least 3 hours prior to testing. The sensitivity of each electrode to nitrate was tested with five standard solutions - 0.00001M, 0.0001M, 0.001M, 0.01M and 0.1M KNO3. The raw voltage readings were corrected for the change in junction potential using the Henderson formula (Morf, 1981) and Debye-Hückel formula was used to calculate the ionic activities for each solution (Meier,1982). The sensitivity of each electrode was determined by linear regression of the corrected voltages against the logarithm of the ionic activities of the solutions. The significance of membrane composition, age, and the interaction between age and membrane composition was tested using the statistical program, SAS. The separate solution method (SSM) was used to determine the selectivity coefficients of the membranes (Ammann, 1986). The selectivity of the membranes for nitrate over the sodium salts of interference ions were determined in the following order; sulphate (Na2SO4), phosphate (Na2HPO4), acetate (CH3COONa), bicarbonate (NaHCO3), chloride (NaCl), bromide (NaBr), Iodide (NaI), chlorate (NaClO4) and thiocyanide (NaSCN). This order was selected so that the ion with the lowest interference would be tested first, followed by ions of increasing interference, to reduce the effects of membrane poisoning by the later tested ions. The extended Nernst equation, and the electrode response for each interference ion were used to determine the selectivity factor. The General Linear Model Procedure (GLM) of SAS was used to determine whether the selectivity factors of the different membranes were different using t tests. Nitrate ISFETs were produced by applying the nitrate ion-selective membrane solutions into the ISFET sensor wells using a micro-syringe. Two different ligands (TDDA, MTDA) and two plasticizers (TOTM, NPOE) were used, with different membrane cocktails placed on each sensor. The four ISFETs were ISFET1 (MTDA/NPOE), ISFET2 (MTDA/TOTM), ISFET3 (TDDA/NPOE) and ISFET4 (TDDA/TOTM). The chip was mounted on a ceramic substrate with pins for a IC socket, and the bonding wires and ISFET surfaces (except for the gate regions) were protected using epoxy resin. The lower portion of the flow cell attached to the top of the multi-ISFET chip, exposing the ISFET gate regions to the solution

The optimal flow rate, and injection and washout times were investigated using the FIA system and multi-sensor ISFET. Four flow rates (0.057, 0.120, 0.179, 0.236 mL/s), three washout times (2, 1, 0.75 s) and four injection times (2, 1, 0.75, 0.5 and 0.25 s) were used to determine the shortest injection and washout times, and the lowest flow rate which provided acceptable results. The FIA parameters were tested using an incomplete factorial block design, since the sample injection time was always equal to or less than the washout time. The blocks, representing a particular combination of washout and injection times, were randomized. Within each block, flow rate and solution concentration combinations were completely randomized. The SAS General Linear Methods (GLM) procedure was used to obtain a linear regression of the response peak height against the logarithm of the concentration for each combination of flow rate, injection time, and washout time. The slopes of the regressions and the

coefficients of correlation for the tests were then compared.
Testing of the ISFET/ FIA system for soil analysis was carried out in two stages: 1) using manually extracted samples, and 2) the soil to be analyzed was placed in the automated soil extraction system, and the extract fed directly into the FIA system. This procedure could be used to determine whether the major source of error was a result of the automated extraction or as a result of error in the nitrate analysis system. An injection time of 0.5 s, and washout times of 0.75 s and 2.5 s, were used during these tests. While a 3 s cycle time is probably too slow for real-time nutrient mapping and control, the tests were included to assess the improvement in precision, if any, and that would result from a longer cycle time. The cycle time is not critical when the nutrient mapping procedure is a separate operation from nutrient application. The nominal flow rate was 0.17 mL/s for all tests.

## VI. RESULTS

The sensitivity response of typical electrodes of each membrane type showed an approximately linear Nernstian response when the nitrate concentrations were above 0.0001 M. However, at low concentrations (0.00001 M) the sensitivity of TDDA membranes decreased more than that of MTDA membranes. Although the decrease in sensitivity at low concentrations varied between individual electrodes; in general, the TDDA membranes showed less sensitivity at low concentrations than did the MTDA membranes. The results from the GLM difference of means procedure reflected the higher sensitivity of the MTDA membranes at low concentrations. The TDDA-TEHP membranes (-55.6 mV/decade) showed the lowest response, followed by TDDA-NPOE, TDDA-TOTM, TDDA-DBP,MTDA-TEHP, MTDA-NPOE, MTDA-TOTM, with the MTDA-DBP membranes (-63.28 mV/decade) having the greatest sensitivity response.

The selectivity's of the membranes were predominantly determined by the ligand type. The TDDA membranes displayed a greater selectivity for nitrate over the interfering species than did the MTDA membranes (Table 1). Differences among the means of the selectivity factors of the two ligands were highly significantly (" < 0.01) for all of the interference ions except thiocyanate (" < 0.02) and iodide (" < 0.18). Differences among the means of the selectivity factors of the plasticizer were not significant (" < 0.05) except in the case of phosphate (" < 0.02), bromide (" < 0.011) and chlorate (" < 0.043). For the tests using the multi-sensor ISFET/FIA system, only the results obtained with ISFET1 (MTDA-NPOE) are reported. The lowest flowrate (0.057 mL/s) was insufficient for complete washout of the flow cell before the next sample was injected, with the possible exception of the 2.0 s washout time. The gradients of the ISFET response for the higher flowrates were essentially zero when the next sample was injected, which signified that complete washout had occurred, for all four injection times (graphs not shown). The response of the ISFET in the FIA system to changes in injection time (0.25, 0.50, 0.75, 1.0, 2.0 s), and at different flowrates (0.057, 0.120, 0.179, 0.236 mL/s) are shown for washout times of 2.0 s and 0.75 s, respectively (Figures 2 and 3). At the highest flowrate, the response peak height was not substantially decreased by a decrease in injection time; thus

***Table 2:*** *Comparison of the means of the selectivity factors by membrane composition, ligand and plasticizer for several interference ions.*

| Selectivity Factor (log K) | HPO4 | SO4 | Ac | HCO3 | Cl | Br | I | SCN | ClO4 |
|---|---|---|---|---|---|---|---|---|---|
| **MEMBRANE COMPARISON** | | | | | | | | | |
| TDDA-TEHP | 3.37c1 | 3.49b | 3.26bcd | 3.08cde | 2.27b | 0.67abc | 0.73abcd | 1.20abc | 1.89bc |
| TDDA-NPOE | 3.69b | 3.73b | 3.45bcd | 3.28de | 2.41b | 0.83e | 1.01abcd | 1.14ab | 2.12bc |
| TDDA-TOTM | 3.12c | 3.32b | 2.87abc | 2.80bcd | 2.27b | 0.88e | 0.99abcd | 0.63bc | 1.91bc |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| TDDA-DBP | 3.78b | 3.66b | 3.21abcd | 3.13cde | 2.35b | 0.77d | 0.40bd | 1.33ab | 0.52d |
| MTDDA-TEHP | 2.58a | 2.31a | 2.50ab | 2.25ab | 1.58a | 0.63ab | 0.98abcd | 1.61ab | 2.65abc |
| MTDDA-TEHP | 2.62a | 2.42a | 2.56ab | 2.36ab | 1.70a | 0.68bc | 1.07abcd | 1.49ab | 2.78ab |
| MTDDA-TOTM | 2.42a | 2.15a | 2.47ab | 2.26ab | 1.67a | 0.65abc | 1.03abcd | 1.43ab | 2.62abc |
| MTDDA-DBP | 2.70a | 2.50a | 2.62ab | 2.47abc | 1.72a | 0.70abc | 1.02abcd | 1.38ab | 2.65abc |

**LIGAND COMPARISON**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| MTDA | 2.60a | 2.38a | 2.55a | 2.34a | 1.68a | 0.67a | 1.04a | 1.49a | 2.72a |
| TDDA | 3.57b | 3.62b | 3.29b | 3.15b | 2.36b | 0.81b | 0.87b | 1.10b | 1.79b |

**PLASTICIZER COMPARISON**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| DBP | 3.30b | 3.15a | 2.95abc | 2.84a | 2.07bc | 0.74bc | 0.68a | 1.35abc | 1.47a |
| NPOE | 3.18b | 3.09a | 3.02bc | 2.83a | 2.07bc | 0.76bcd | 1.04a | 1.31abc | 2.44a |
| TEHP | 2.93a | 2.84a | 2.84abc | 2.62a | 1.89ab | 0.65a | 0.87a | 1.43ab | 2.31a |
| TOTM | 2.86a | 2.88a | 2.72abc | 2.60a | 2.05abc | 0.79cd | 1.01a | 0.93bc | 2.18a |

The dispersion factor at the peak maxima was approximately 1 and the sample slug at this point was undiluted. At the two intermediate flow rates (0.12 and 0.179 mL/s), response peak heights for the 0.25 s injection time were lower than for the longer injection times, showing that the maximum dispersion factor was less than 1 and the sample slug was diluted even at the peak maximum, although the response peak heights were only reduced by 25 percent of the maximum. The 0.75 s washout time showed the same trends as the 2 s washout time, with low flow rates resulting in lower response mean peak heights due to carryover and short injection times resulting in reduced response peak heights due to dispersion. These response curves demonstrated that even with an injection time of only 0.5 s, the response is satisfactory, provided that the flowrate is high enough for adequate washout of the flow cell. An increase in injection time beyond 0.5 s does not significantly affect the peak height but does increase the peak width at the baseline which increases the minimum washout time required. An increase of flowrate from 0.12 mL/s to 0.236 mL/s did not significantly increase the response peak height but did decrease the peak width. The overall precision of the system was dependent on maintaining precise repetitive injection times and ensuring the flow parameters did not change. The injection valve used in this study was operating at the upper limit of its sampling rate, which was the major cause of variation in output response. The small dimensions of the ISFETs allow very high sampling rates since dispersion is decreased, and the correct selection of flowrate and injection time allow a sample period of less than 2 s. The multi-sensor ISFET/FIA system was calibrated before the analysis of manually extracted samples using standard solutions. The ISFET predicted concentrations of manually extracted soil solutions were compared to the actual soil concentrations determined using the cadmium reduction method (Lachat Analyzer) on the identical solutions

## VII. ADVANTAGES

(1) No centrifugal Switch
(2) Less harmonics
(3) No zero current switching
(4) Steady state current minimized
(5) More economical
(6) Better efficiency
(7) Less Maintenance cost

## VIII. APPLICATIONS

(1) Woodworking machines
(2) Ice cream mixture and compressor
(3) Agricultural applications
(4) Horticulture

## IX. PROBLEMS ENCOUNTERED

(1) Water level sensors should be placed in appropriate place such that there is uniform distribution of water all over the area, else the water level sensors might give a wrong output.

(2) The ratings of the capacitors are decided based on the impedance of the circuit- if the capacitors are not designed properly the capacitors may even burst

(3) As high voltage capacitors are used the switch should be capable of withstanding the high voltage surges produced hence care should be taken while deciding the rating of IGBT.

## X. CONCLUSION

The design and implementation of a controlled capacitor for a three-phase induction motor operating from single phase supply has been presented by using a fixed capacitor in series with an electronic switch. The proposed system eliminates the use of mechanical or centrifugal switches which is located inside the motor. This avoids the possibility of the switch failure and leads to less operational and maintenance cost and improves the system reliability. The optimum effective capacitor value can be on-line adjusted at any operating speed by periodically changing the duty cycle of the controlled switch to achieve minimum unbalance in phase voltages or any other optimization criteria to improve the motor performance at different speeds. With the output obtained from the hardware module, it can be inferred that the automation of the irrigation system is highly feasible so that the irrigation can be done even without the presence of farmer.

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## BIOGRAPHY

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