Development of an Outage Management System for Power Distribution Networks

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***Abstract* – We propose a system to alert an end user of an imminent outage to prepare for it and attend a base station before an electrical shutdown. A literature review on various studies proved no existence of such a power outage telecommunications relational system but a system called outage management system has the same operational principle but different end goal. Our outage management system aims at quick identification of outages and restoration than the system developed for the Botswana Power Corporation. Mains failure monitoring and power support management System aims at alerting telecommunication preventative maintenance technicians on future outages ahead of time and enlists all the base stations to be affected by the grid outage, base station priority is also considered on the list which governs which base stations to attend to. When there is a mains failure the generators to be started makes the delay in connecting the network. Mains failure monitoring and power support management system is intended on creating a relational database management system to be used by a Power distribution operator that interlinks the power grids of a town to the base stations (sites) and then run queries to test the system's response to data filtering. Our database system was able to accept information of future power outages and the queries run on different parameters displayed accurate results hence meeting the objective.**

Keywords - outage management system; failure monitoring; power distribution; restoration.

I. INTRODUCTION

Outage management is a systemic approach used by operators of the electric distribution network to help in restoring power after a power cut. This is implemented through an Outage Management System (OMS) which is a system of computer-based tools designed to be aware of any power outage with or without customer intervention. For an OMS to be fully efficient, it must be integrated with other sub-systems with up-to date data. Power outages can be classified as temporal or permanent depending on timing limits set up by power distributing companies [1].

The initial step in any OMS is outage detection. The basic operations of an OMS are to check, analyze, notify/report on outages and lastly restoration of outages [2]. Outage Management systems are designed to be aware of power outages, to diagnose the possible outage causes, to know the affected scope and to finally formulate a solution to tackle the problem promptly which in most cases involves sending a repair crew to attend to the fault. Effective outage detection is the ideal requirement of an outage management system, which is being able to detect power outage before a customer complaint call, a failure in auto detection is bridged by customer calls where a call center receives calls from customers and this was the traditional approach to outage detection [3]. Alternatively, Interactive Voice Response (IVR) may be used to lodge in complaints. Customer complaint calling is unreliable since it is dependent on when the outage occurs, at night the efficiency of customer complaint calling as a way of identifying outage detection is significantly less since people are likely to be sleeping [4]. The OMS includes a Geographic Information System (GIS) interlinked to customer information, the customer's home or business is linked to the distributing transformer and when an outage call is made, relevant information is obtained and a search engine is then engaged to project an affected location. The customer trouble calls formulate a grouping which assists in tracing the affected topology [5], this is the purpose of the GIS.

At the center of an advanced blackout the board framework is a point by point arrange model of the circulation framework [6]. The utility's Geographic Data Framework (GDF) is normally the wellspring of this system show. By joining the areas of blackout calls from clients, a principles motor is utilized to anticipate the areas of blackouts [7]. For example, since the conveyance framework is fundamentally tree-like or outspread in plan, all brings specifically zone downstream of a wire could be gathered to be caused by a solitary wire or electrical switch upstream of the calls. The blackout calls are typically accepted by call takers in a call focus using a Client Data Framework (CIF). Another normal path for blackout calls to go into the CIF (and in this way the OMS) is by coordination with an Intelligent Voice Reaction (IVR) framework. The CIS is likewise the hotspot for all the client records which are connected to the system display. Clients are ordinarily connected to the transformer serving their habitation or business. It is imperative that each client be connected to a gadget in the model so exact insights are

inferred on every blackout. Clients not connected to a gadget in the model are alluded to as fuzzy. Further developed programmed Automatic Meter Reading (AMR) frameworks can give blackout identification and reclamation capacity and in this manner fill in as virtual calls demonstrating clients who are without power. Notwithstanding, one of a kind qualities of AMR frameworks, for example, the extra framework stacking and the potential for false positives necessitates that extra principles and channel rationale must be added to the OMS to help this integration [8].

Blackout the board frameworks are likewise usually incorporated with Supervisory Control and Data Acquisition (SCADA) frameworks which can naturally report the task of observed circuit breakers and other keen gadgets, for example, SCADA reclosers [9]. Another framework that is generally incorporated with a blackout the board framework is a versatile information framework. This incorporation gives the capacity to blackout forecasts to consequently be sent to groups in the field and for the teams to have the capacity to refresh the OMS with data, for example, evaluated rebuilding times without requiring radio correspondence with the control focus [10]. Groups additionally transmit insights concerning what they did amid blackout rebuilding. It is imperative that the blackout the executives framework electrical model be kept up to flow with the goal that it can precisely make blackout expectations and furthermore precisely monitor which clients are out and which are reestablished [11]. By utilizing this model and by following which switches, breakers and wires are open and which are shut, organize following capacities can be utilized to distinguish each client who is out, when they were first out and when they were reestablished [12]. Following this data is the way to precisely announcing blackout insights

Action taken to provide restoration goes through evaluation or diagnosis of what might be causing the outage, possible reasons include; transformer faults, open lateral fuses, fallen poles and a few others, this then gives an admonition on crew dispatch management weighing the work load of the probabilistic cause [13]. Studies on OMS indicate that together with Business Process Management (BPM) lessened time for locating outage by 30% also reducing personnel and equipment costs by approximately 25% [14]. These reductions in cost and personnel are attributed to Service Oriented Architecture (SOA) which is a fusion of services operating together to obtain results in a certain activity. The business aspect of SOA involves BPM which merges the technical part of an activity under inspection with the managerial aspect to formulate a cost-effective approach towards running operations [15-17]. AMR is another technological advancement under automated meter reading systems that have capabilities in outage detection and restoration, also, a newly introduced meter technology called Advanced Metering Infrastructure (AMI) has capabilities on real time outage notification and restoration. The AMI is a bidirectional communication system which has enabled faster outage recognition and resultantly shorter recovery time. These automated meter reading systems are implemented through varying technologies including; GSM, ZigBee, SCADA, WiMAX and a combination of either one of the listed with another to form a hybrid. The automated meters act as virtual calls and on an occurrence of power outage they indicate the absence of power at the operator, if multiple meters signal for outage it signifies a major outage as compared to one meter which may imply a household fault. The Fig.1 shows the basic outage management system structure.

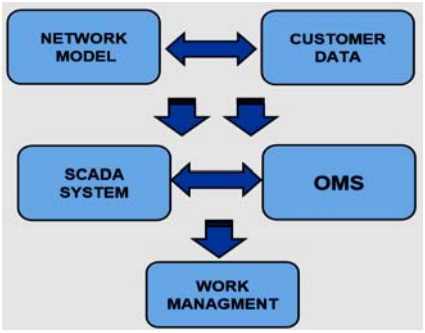


Figure 1. Basic OMS Structure showing the interaction of Customer data with various bodies in deducing a reliable Outage Management System

Power distribution operators aim at improved quality service to the customer, outage management has proved to be beneficial to the organization in lowering costs and consequently improving customer service, added benefits include accuracy in locating outages in the topology, faster attendance time and less personnel required to attend an outage.

The chapter two explain about the telecommunication preventative maintenance, power support and mains failure. The chapter three and four explains about the problem statement and existing system. The chapter five and six explains introduction of the proposed system and system design. The chapter seven and eight explain about the discussion and conclusion.

II. Telecommunication Preventative Maintenance, Power Support And Mains Failure

Telecommunication Preventative Maintenance (TPM) is planned periodic maintenance carried out to prevent against equipment failure. A telecommunication service provider usually contracts a company to carry out the preventative maintenance of its base stations or priority sites, telecommunication preventative maintenance has scheduled duties which are carried out in accordance to plan and these include; air conditioner PM, diesel generator PM, site cleaning/ inspection, battery testing and tower inspection. The non-scheduled task is an emergency

duty called power support carried out during occasions of mains failure or power outage.

Mains failure also termed power outage is the absence of mains power in the Radio Broadcasting Station (RBS) and it results mostly from power cuts by the BPC (Botswana Power Corporation), bad weather, power cable faults, tripped switches and absence of electricity units in the smart meter. Power support is a preventative measure to power outage and done by attending a base station which has reported for mains failure and powering it up with a portable or mobile generator, highest priority sites have their own stand-by generators which run immediately when power goes off because they are required not to go off air at any instant. Power support is carried on evaluation of priority sites, that is high priority base stations over low priority base stations even though it is currently based on first come first serve basis, that is, whichever site reports first is attended to unless a higher priority site gives an alarm to be attended to as well. The essence of power support is to ensure that there is continuous network availability and ideally less downtime.

III. Problem Statement

Power outage is due to a few reasons of which some are deliberate, for example; a BPC schedule for replacing transmission cables and poles, transformers maintenance and any maintenance duty that requires power to be cut, all this done to maximize power transmission efficiency. BPC can either issue a communique on their web page for their schedules, share their planned interruptions on radio stations or one can call their offices to query on their schedules. These means of dissipating information are unreliable to a customer since they are broadcasted and not direct and thereby when power goes off it negatively affects businesses and multiple telecommunication sites also report for mains failure.

These power outages affect multiple sites since the BPC may work on a transmission grid which covers more than one area/village and this causes confusion when a technician attends one site for power support because during the process another high priority site can be called in for power support. When a site goes off air for an extended period there would be no network coverage and it is considered a loss to the service provider since people would not be able to make calls, send text messages, access the internet or make online banking transactions.

IV. Exisitng System

BPC employs the use of their website, radio stations and social media to inform the nation on their planned power outages where they list all the affected villages or geographic area and indicate the purpose of the power cut together with the duration it will take to complete the task. A customer is also open to contact the relevant branch office to query about any forefront power cuts in their area. These means of information dissipation are broadcasted and hence the chances of obtaining the messages depend on one's exposure to the means used to dissipate such information.

A. Problems with the Existing System

The schedules are broadcasted hence the probability of obtaining information on these schedules depends on one's exposure to such means of information dissipation, e.g. the radio or social media. To check on planned outage schedules power reliant on customers engages extra effort and resources by either accessing the BPC website or by calling the relevant BPC branch in order to obtain the desired results. The Fig.2 shows the power interruption schedule in the BPC website. The schedule entails areas affected, dates, switch off times and restoration times.

Figure 2. BPC Power interruption schedule on the BPC website.

V. Proposed System

To counterfeit the problems of the existing system including poor information dissipation for the power reliant on customers is to create an application program that composes of the electrical distribution grid of a town for every town in a country and including a certain service provider's sites under each grid for each town. This program ought to act as a real time notification panel on BPC power cut schedules, emergencies and to serve as an opinion advisor on which base stations to power support since some stations may be high priority over others. With this application if the BPC are bound to work on a certain task they indicate from their server and the program gives a real time notification on the application used by service provider's technicians together with sites to attend for power support.

A viable solution would be creating a mail responsive web application where the BPC indicate from their server and the program gives a real time notification to the receiver along with sites to attend for power support. The proposed system is built on Visual Studio obtaining

records from MS SQL Server. The initial step is database design which focuses on creating a relational database management system using MS SQL server composing of the BPC table, power grids table and the sites (base station) table. Each table created entails its own set of information and has column names where data is inserted into columns. Primary keys are identified for unique fields in each table and foreign keys also exist when a relationship is established between two tables or more. The Fig.3 given details about the BPC branch grid and site code for the reference. The Fig.4, Fig.5 shows the grids data and sample data in MS SQL Server. The Fig.6 shows the statement is a query to obtain sites under Grid code B2002, where B2002 is the affected grid. Fig.7 shows all the sites queried under grid B2002 alongside site priority for each site. Fig.8 is a query to obtain sites under Grid code A1001, where A1001 is the affected grid. Fig.9 shows all the sites queried under grid A1001 alongside site priority for each site.

Figure 3. Table planning on the required tables to create a database with. Three (3) required tables include: BPC table, Grids table and Sites table.

	GridCode	Grid_Name
	A1001	PalapyeWest ...
	B2002	PalapyeNorth ...
	C3003	PalapyeEast
	D4004	PalapyeSouth ...
▸*	*NULL*	*NULL*

Figure 4. Sample Grid Data on the Grids Table (MS SQL Server)

	SiteCode	Site_Name	SitePriority	GridCode
▸	Ply02	Extension7	P2	B2002
	Ply08	Madiba	P4	C3003
	Ply29	Extension9	P3	D4004
	Ply54	Khurumela	P2	A1001
	Ply55	Thabala	P4	D4004
	Ply57	Boseja	P3	A1001
	Ply59	Bokhurutshe ...	P4	A1001
	Ply61	Tlhomadithots...	P4	A1001
	Ply90	Extension11	P3	C3003
	Srw03	SeroweMokwe...	P3	B2002
	Srw06	SeroweCTO ...	P2	B2002
	Srw10	Metsimasweu ...	P2	C3003
	Srw16	SeroweBTC	P2	C3003
	Srw39	SeroweCBD ...	P4	D4004
*	*NULL*	*NULL*	*NULL*	*NULL*

Figure 5. Sample Data on the Sites Table (MS SQL Server)

```
insert into BPC (BPC_Branch_Code, Planned_Outage_Emergency,
                 Interruption_Date, Time_To_Completion,
                 GridCode_Affected)

                values ('BPC1','Emergency','2018/02/12','05:00:00', 'C3003')

insert into BPC (BPC_Branch_Code, Planned_Outage_Emergency,
                 Interruption_Date, Time_To_Completion,
                 GridCode_Affected)

                values ('BPC2','Planned','2018/06/12','07:00:00', 'D4004')

UPDATE BPC
 SET Interruption_Date = '2018/04/12' , Gridcode_Affected= 'B2002'
 WHERE BPC_Branch_Code = 'BPC1';


 SELECT * FROM BPC

 SELECT Site_Name , SitePriority FROM SITES where GridCode like 'B2002'
```

Figure 6. A test to review the database's response to query testing.

MainsFailureMonito...nt System (sa (52))

Editor | Results

Site_Name	SitePriority
Extension7	P2
SeroweMokwena	P3
SeroweCTO	P2

(3 row(s) affected)

Figure 7. Results obtained from the query test

```
insert into BPC (BPC_Branch_Code, Planned_Outage_Emergency,
                 Interruption_Date, Time_To_Completion,
                 GridCode_Affected)

               values ('BPC2','Planned','2018/06/12','07:00:00', 'D4004')

UPDATE BPC
SET Interruption_Date = '2018/04/12' , Gridcode_Affected= 'B2002'
WHERE BPC_Branch_Code = 'BPC1';


SELECT * FROM BPC

SELECT Site_Name , SitePriority FROM SITES where GridCode like 'A1001'
```

Figure 8. A test to review the database's response to query testing

MainsFailureMonito...nt System (sa (52))*

Editor | Results

Site_Name	SitePriority
Khurumela	P2
Boseja	P3
Bokhurutshe	P4
Tlhomadithotse	P4

(4 row(s) affected)

Figure 9. Results obtained from the query test.

A. Delete Function

The deletion of input data is carried out using a delete statement based on a condition of date, a record would automatically be deleted if it is a day old from the current date, that is input only lasts for 24 hours. This is to save space and avoid over flooding of input in the system. Fig.10 which deletes content based on date. Future date is referenced to current date and records which are 24 hours ahead of current date are deleted from the database.

```
               values ('BPC4','PLANNED','2018/06/11','07:00:00', 'A1001')

DELETE FROM BPC
WHERE Interruption_Date < GETDATE() - 1

UPDATE BPC
SET Interruption_Date = '2018/04/12' , Gridcode_Affected= 'B2002'
WHERE BPC_Branch_Code = 'BPC1';
```

Figure 10. A MS SQL Server Delete Function.

B. Testing the Delete Statement

Records of power outages on future schedules, current date's schedule and overdue schedules are shown in Fig.11. The Fig.12 shows the power outage schedule before execution of the delete statement.

Figure 11. Computer's current date and time.

```
SELECT * FROM BPC
```

100 %

Results | Messages

	BPC_Branch_Code	Planned_Outage_Emergency	Interruption_Date	Time_To_Completion	GridCode_Affected
1	BPC 253	EMERGENCY	2018-07-14	06:00:00.0000000	A1001
2	BPC 321	EMERGENCY	2018-07-21	03:00:00.0000000	A1001
3	BPC 3454	PLANNED	2018-07-06	04:00:00.0000000	B2002
4	BPC103	EMERGENCY	2018-06-16	02:00:00.0000000	D4004
5	BPC112	EMERGENCY	2018-08-16	04:00:00.0000000	B2002
6	BPC412	PLANNED	2018-07-16	07:00:00.0000000	C3003

Figure 12. Power outage schedule before execution of the delete statement. The list consists of all the schedules.

All the schedules before the current date are automatically deleted after the execution of delete function, the results are shown on Fig.13.

Results | Messages

	BPC_Branch_Code	Planned_Outage_Emergency	Interruption_Date	Time_To_Completion	GridCode_Affected
1	BPC 321	EMERGENCY	2018-07-21	03:00:00.0000000	A1001
2	BPC112	EMERGENCY	2018-08-16	04:00:00.0000000	B2002
3	BPC412	PLANNED	2018-07-16	07:00:00.0000000	C3003

Figure 13. Power outage schedule after execution of the delete statement. Dates before 16/07/2018 have automatically been deleted. The remaining dates are future schedules.

VI. SYSTEM DESIGN, TESTING AND RESULTS AND DISCUSSION

A. Designing a Mail Responsive Web Applications

Designing a mail responsive web application involves the connecting an SQL server to Visual Studio then designing the layout of the interface. The second step involves linking each field of the interface to an SQL command using C# and testing the interface via a local server.

B. Connecting SQL Server to Visual Studio

The aim of this step is making the interface reliant on the database source created therefore the MSSQL server is

connected to Visual Studio 2015. A connection is made using the SQL server explorer option whereby a local database host is added as a connection to Visual Studio. A connection string is automatically established after a successful connection.

C. Designing a Layout of the Interface

This entails designing a page layout together with User Interface (UI) elements. Interface elements include; display functions, input controls, navigation tools and more controls depending on designer requirements. The design of the Mains Failure Monitoring and Power Support Management system interface required a page layout inclusive of textboxes, buttons and display controls, two page tabs were designed for this system, the login page and the operations page where input and output operations are handled. The Fig.14 shows the design layout of the operations page 1 and Fig.15 shows the design layout of the operations page 2.

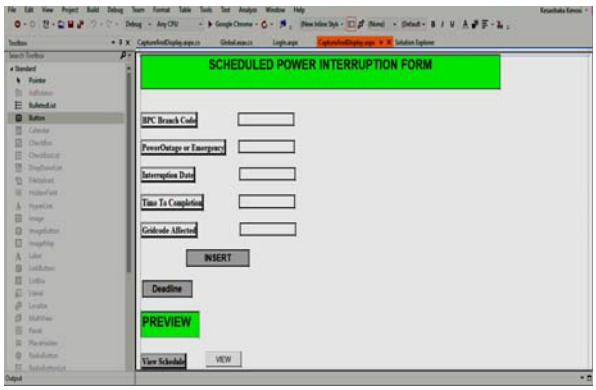


Figure 14. Design Layout of the operations page 1 using Visual Studio 2015.

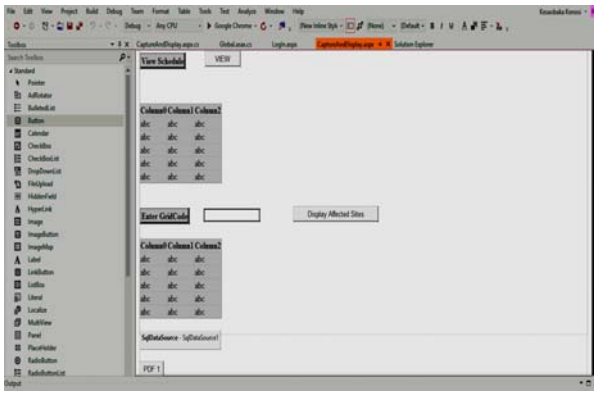


Figure 15. Design layout of the operations page 2.

D. Linking Each Field of the Interface to an SQL Command Using C#

The Mains Failure Monitoring and Power Support Management user interface is database hosted as a result the interface ought to operate with regard to the local database. It is a process of referencing a textbox, button and/or a display function to an SQL statement in the database code. Achieving operation of controls is facilitated through coding, C# was used in serving this purpose it is shown in Fig.16.

Figure 16. C# Code for the Login Page

E. Testing the Interface Via a Local Server

Once the coding is complete, controls are tested on a local server provided by Visual Studio 2015. [5]IIS short for Internet Information Services is a web server developed by Microsoft to enable web services for operating systems running on Windows. Internet Information Services (IIS) plays the role of a web server, providing interactive webpages and responding to user requests. It supports protocols like HTTP, SMTP, FTPS and many more depending on the version.

ASP.NET Core is an Active Server Page (ASP) framework for producing interactive webpages. It is a server-side based framework that allows web requests and the request are forwarded from the IIS server to the ASP.NET application which references the request and produces a response. Microsoft Visual Studio is an example of applications that run ASP.NET core frameworks hence its capability of content management over the web. The Fig.17 shows the accurate Log-In Details Direct to the Operations Page where a user inputs future schedules or outputs the already existing ones. The Fig.18 shows the testing the operations page through a query based on grid code. The two column table below shows the results

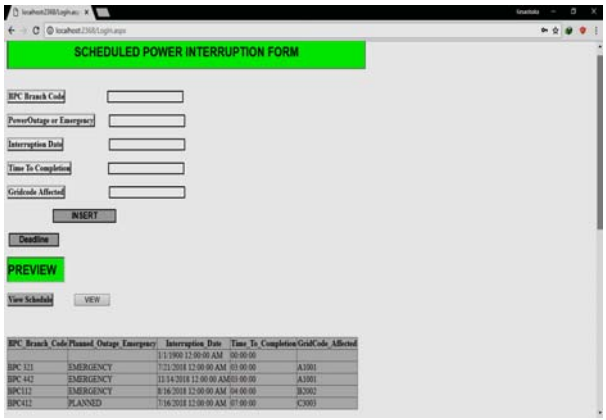
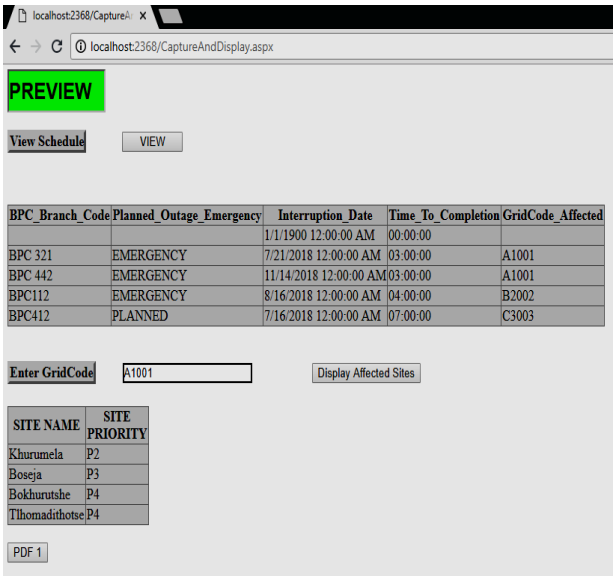


Figure 17. Accurate Log-In Details Direct to the Operations Page.



BPC_Branch_Code	Planned_Outage_Emergency	Interruption_Date	Time_To_Completion	GridCode_Affected
		1/1/1900 12:00:00 AM	00:00:00	
BPC 321	EMERGENCY	7/21/2018 12:00:00 AM	03:00:00	A1001
BPC 442	EMERGENCY	11/14/2018 12:00:00 AM	03:00:00	A1001
BPC112	EMERGENCY	8/16/2018 12:00:00 AM	04:00:00	B2002
BPC412	PLANNED	7/16/2018 12:00:00 AM	07:00:00	C3003

SITE NAME	SITE PRIORITY
Khurumela	P2
Boseja	P3
Bokhurutshe	P4
Tlhomadithotse	P4

Figure 18. Testing the operations page through a query based on grid code.

F. E-Mail Sending Results

The SMTP extension loaded into visual studio enables mail sending capabilities. The sender's mail address remains fixed within the code, the user is only bound to input the receiver's mail address. A secure socket layer was enabled to allow for a secure connection. The Fig.19 shows the Inserting the recipient's address and subject of the mail, the message body is a query statement executing in the code. The Fig.20 shows the recipient's mail address receiving the power-cut schedules.

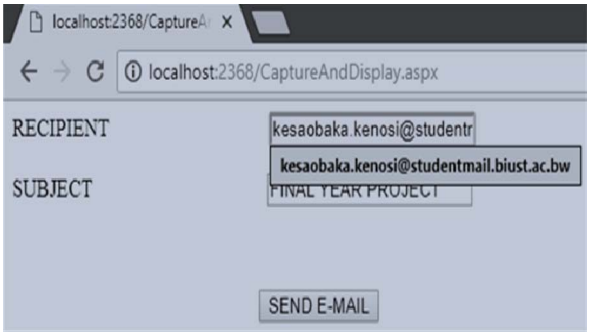


Figure 19. Inserting the recipient's address and subject of the mail, the message body is a query statement executing in the code.

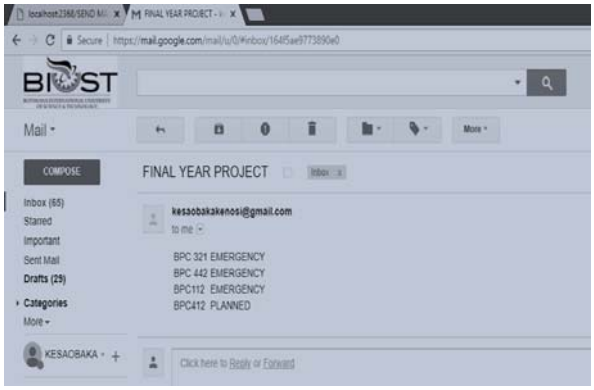


Figure 20. The recipient's mail address receiving the power-cut schedules.

VII. Discussion

A mobile responsive application can also serve similar functions like those of a mail responsive application the difference being the means of data receipt, instead of receiving an e-mail a mobile responsive application requires a dedicated mobile application on which alerts are made on. This application software will be installed on a mobile device and solely meant for receiving information on base stations requiring power support in the nearby days.

Both applications require connection to the internet hence a receiver in a poor network zone may not be able to go online and access mail. The drawback of this online procedure could be mitigated by Short Message Services (SMS) duplicating similar information in the mail message to cater for an offline receiver.

VIII. Conclusion

Database design as part of the system created a framework of data to work with. Operations with this data involve data input/output and deletion depending on the user. A web based interface is linked to the database and becomes a portal from which mail messages can be sent The capability of the system to respond to data filtering and furthermore relay the required data by mail to a recepient

accomplishes the objective of a mail-responsive web application.

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