Prevention of Electricity Theft using Distribution Board Remote Switch Control (DBRSC)

Md Zulkifili Mohamad[1*], Norzanah Rosmin[2], Muhalim Mohamed Amin[3], Aede Hatib Mustaamal[4], Nor Azizah Ali[5], Aripriharta[5]

[1] TNB NERCC, Tingkat 5, No.3031, Wisma TNB, Jalan Tenaga 13700 Seberang Jaya, Pulau Pinang, Malaysia.
[2*] Centre of Electrical Energy System (CEES), POWER Department, School of Electrical, Faculty of Engineering, Universiti Teknologi Malaysia, 81310 Johor, Malaysia.
[3] School of Computing, Faculty of Engineering, Universiti Teknologi Malaysia, 81310 Johor, Malaysia.
[4] School of Education, Faculty of Social Sciences and Humanities, Universiti Teknologi Malaysia, 81310 Johor, Malaysia.
[5] School of Computing, Faculty of Engineering, Universiti Teknologi Malaysia, 81310 Johor, Malaysia.
[6] Electrical Engineering Department, Universitas Negeri Malang, Jl. Semarang No 5. Sumbersari, Lowokwaru, Malang, East Java, Indonesia.

Corresponding author* email: norzanah@utm.my
Received x July 20XX; accepted XX XX, available online X December 20XX

ABSTRACT

One of a major problem in many developing countries is electricity theft. In Malaysia, the most common forms of stealing electricity are tapping electricity directly from the distribution feeder and manipulating the meter reading via tampering. Refuse to pay bills also one of the problem contributors. Many electric utilities face this problems, Tenaga Nasional Berhad (TNB) as the largest electric utility in Malaysia, is no exception. To counter the power theft problem, disconnecting the offenders' electric supply is a popular approach attempted by TNB for many years. However, this has caused a lot of hazardous events such as injury and potentially loss of life. Therefore, in this paper, a more practical and safer solution is proposed to counter this issue, in which a Distribution Board Remote Switch Control (DBRSC) control approach is proposed. To design this DBRSC, an Arduino Uno microprocessor was used to communicate with an MIT V3 smartphone app using MIT App Inventor Software. From the experimental test, it has been found that the proposed DBRSC unit has been successfully designed, developed, and functioning well in disconnecting and reconnecting the electrical supply remotely. This DBRSC also has been proven works well for both single and three-phase distribution systems. It is therefore, as implication, TNB's technicians able to cut the electricity connection of the electricity thefts' premises and houses easier and safer as the electrical connection can be switched off/on from the installed DBRSC on the substation posts on the streets.

Keywords: Electricity theft, Distribution board, Remote Switch Control

1. Introduction

In Malaysia, the occurrences of electrical power theft across the residential and industrial premises have caused a significant amount of revenue losses to Tenaga Nasional Berhad (TNB), which is one of the largest electricity utilities in Peninsular Malaysia. Recently, the problem of electricity theft at the TNB Distribution sides becomes more serious. In 2011, it was reported in [1] that TNB had lost at RM500 millions annually as a consequent of power theft cases. In [1] also, it has been reported that after using high-tech power meters and new software, together with a beefed-up enforcement team and better coordination with government agencies, the number of cases recorded in TNB's financial year 2011, which is ended in August shot up to 24,659 cases. The number is a surge from TNB's 2009 and 2010 financial years, during which 8,871 and 9,350 cases were recorded, respectively. In 2017, the number of cases has even much been reduced in which 870 electricity theft cases have been detected on the residential and commercial premises, based on 5,385 inspections [2]. The residential premises however were recorded as the highest offender. Based on the figures collected in years 2011 and 2017, the number of electrical power theft cases can be much reduced recently due to the benefits of power smart meter application.

In general, there are number of ways how electrical power is lost including broken/damage/malfunction electric meters, illegal connections, billing irregularities, and unpaid bills [3]. These losses are called as Non-Technical Losses (NTLs). However, among these losses, electrical power theft (illegal connections) problem has been recognized as the most crucial one. The problem related to electrical theft cases may lead to the problems of higher capital cost, safety issue and unbalanced loads at the distribution system [4]. Practically, electrical power at certain locations will be supplied based on the load estimation and required load demands. Hence, when some of the supplied power has been stolen or tapped at the distribution lines and this will disrupt the existing system operation. Besides, the illegal connections are usually done by two methods; household energy meters and pole side at the distribution lines. For the former method, thieves simply bypassing the wire directs to the main supply, or bypassing the wire connections before and after the energy meter reading unit as shown in Figure 1(a) and Figure 1(b), respectively.

(a) (b)

Figure 1. Illegal connection via (a) direct connection to main supply [5] and (b) bypass wire [6]

As prevention for this problem, many approaches have been proposed and executed as this problem happen around the world. In addition, TNB has also taken some precautionary measures on this problem. There are three methods that have been done by TNB to identify the electrical power thefts at the distribution system, which are smart meter data analysis for Power Theft Detection (PTD), load profiling monitoring, and Remote Meter Reading (RMR) [7][8]. These methods give some positives impact on national and state energy in the future. Moreover, this system will facilitate the national energy staffs to confine this theft cases easily and quickly.

2. Electrical Power Theft

Electricity theft is a common issue that facing by most electrical utility companies around the world. For example, Malaysia and Thailand have shared their problem and agreed to solve this issue through the Provincial Energy Authority (PEA). This has been done sometimes ago and both countries still searching the promising methods in solving this problem continuously, from time to time. This is very crucial to avoid serious financial crisis due to lack of profits, lack of funds for investments and lack budgets for the improvement in the power system.

As stated before, Non-Technical Loss (NTL) is primarily related to electrical theft and customer management processes where there are many ways to deliberately cheat utilities [8]. The NTL electrical loss factors generally including a breakthrough the meter so that the meter with lower rate is used, stealing bypassing the meter or making an illegal connection, set false readings by braking meter readers, and prepare bail deviation with internal help workers in a way like subterfuge such as lowered the bills by adjusting the decimal point position on the bills or just ignore unpaid bills [9][10]. From the study, it has been found that electrical power theft usually performed by modifying the meter reading by slowing down the meter movement by placing a bar of magnet closed to the meter [5] as shown in Figure 2(a). Another methods are avoiding the meter reading by shortcutting a cable from the loads and the power supply (meter is not connected) and bypassing wire between the connections as shown in Figure 2(b) and Figure 2(c), respectively [6].

(a) Slowing meter reading (b) Shortcut electrical connection

Figure 2. Electrical Power Theft Methods

There are some of impacts due to the electricity theft. It can cause significant amount of revenue losses to electric power utilities. For TNB case, the losses have been estimated of about RM2 million, based on recorded data [11]. It also contributes to the power quality problems are rising as the thefts consume more energy than that was estimated and supplied by the utility companies [3]. Moreover, the transformers will overload, and hence creating voltage unbalance problems and as the consequence of this, the steady state voltage drops on the system buses as the thefts use more energy than the transformer rated power [12]. Generally, the electricity theft also may reduce overall economic productivity of a country.

The technique used in detecting electricity power theft basically comprises the details of customers' load profile, data pre-processing, detection module, post-processing stage and also suspects determination stage as shown in Figure 3 [13]. In the first stage, customer billing data is collected through various sources such as sensors, manuals, and so on. This data is collected in raw form before first processed. Under second stage, data will be analyzed under the pre-processing module in which data cleaning process will be performed. Here, problems such as missing values are managed in customer billing data and data integration is done to represent the data in the specific form required to process further data. Thirdly, the detection module is executed where data will be classified in order to find the difference or abnormal behavior in the usage pattern through different mechanisms. This detection can be assumed as the hardware-based technique that applied to the electrical theft detection through physical check approach at the premises. The use of electricity needs to be changed at a certain time so that potential fraudulent customers have been identified. Fourthly, the processing of data poses that are usually related to the accuracy of finding a potentially fraudulent customer fraud increase. Through this customer's data processing, suspected customer can be identified.

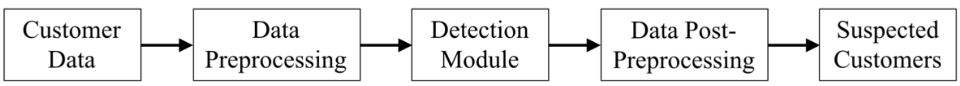


Figure 3. Basic Theft Detection System [13]

3. System Design

In this study, solution for the electricity disconnection by TNB's staffs is proposed by using the ON/OFF switching mechanism through Distribution Board Remote Switch Control (DBRSC) approach. Using this method, TNB's staffs do not need to cut the electrical connection at the customers' premises or houses anymore. This activity can be done remotely from the mobile phone that was installed with a special MIT Apps for the DBRSC approach.

Figure 4 illustrates the diagram of a simple configuration of the proposed ON/OFF switching through Distribution Board Remote Switch (DBRS) Control. This distribution system explains the main supply of electricity through the 11kv step down to 415V system and the distribution takes place through the feeder pillar which is a three-phase supply to single phase of supply through overhead line and then to the premise as an example of a HOUSE 1 (three phase supply), HOUSE 2 (single phase supply) and HOUSE 3 (single phase supply). Meanwhile Figure 5 depicts the flow of the proposed system functionality. First, MIT Apps Inventor V3 will play a major role for overall control over smart phones. after which, bluetooth will choose between house 1, house 2 or house 3. If the cut connection selection will select yes to house 1 (relay 1, relay 2 and relay 3) will be off simultaneously in 3 phase supply system, when to make connection back house 1 (relay 1, relay 2 and relay 3) will be selected for re-opening until the cycle ends. Likewise, the function at house 2 and house 3 but the difference is only a single phase supply system. When choosing to cut connection it will be yes to house 2 (relay 4) will be off in single phase supply system, when want to make connection back to house 2 (relay 4) will be re-opening until the cycle ends. In addition, when choosing to cut connection it will be yes to house 3 (relay 5) will be off in single phase supply system, when want to make connection back to house 3 (relay 5) will be re-opening until the cycle ends.

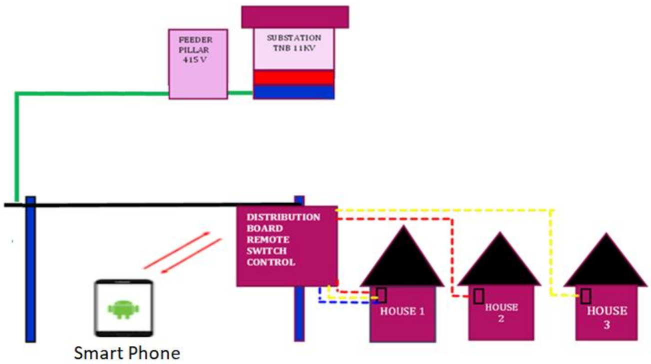


Figure 4. Illustration of the proposed ON/OFF switching through Distribution Board Remote Switch (DBRS) Control

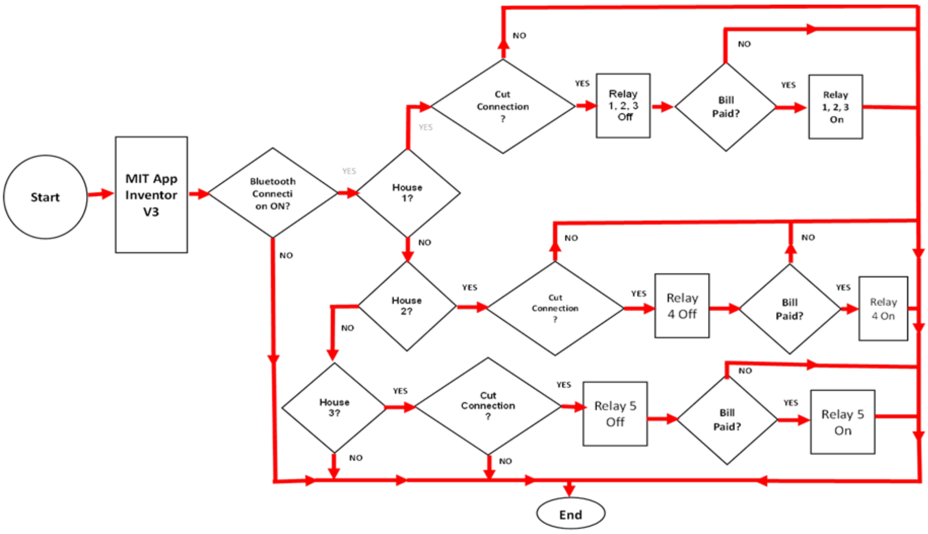


Figure 5. The Proposed Flow of the System Functionality

In Figure 6, the general diagram of the proposed DBRSC system is shown. As shown in the figure, it can be seen that the power supply AC to DC 230V/5V must be supplied to Arduino Uno ATmega328 to power up the circuit. Next, the Bluetooth HC-05 is connected to the Arduino Uno ATmega328 to enable data transfer from the developed DBRSC system and the MIT Apps for DBRSC unit. Power supply 5V will be supplied to Relay 1, Relay 2, Relay 3, Relay 4 and Relay 5. The output of the 5 Relays then needs to be connected to a Voltage ampere meter before connecting the end circuit to the LED bulb in houses, let say House 1, House 2 and House 3.

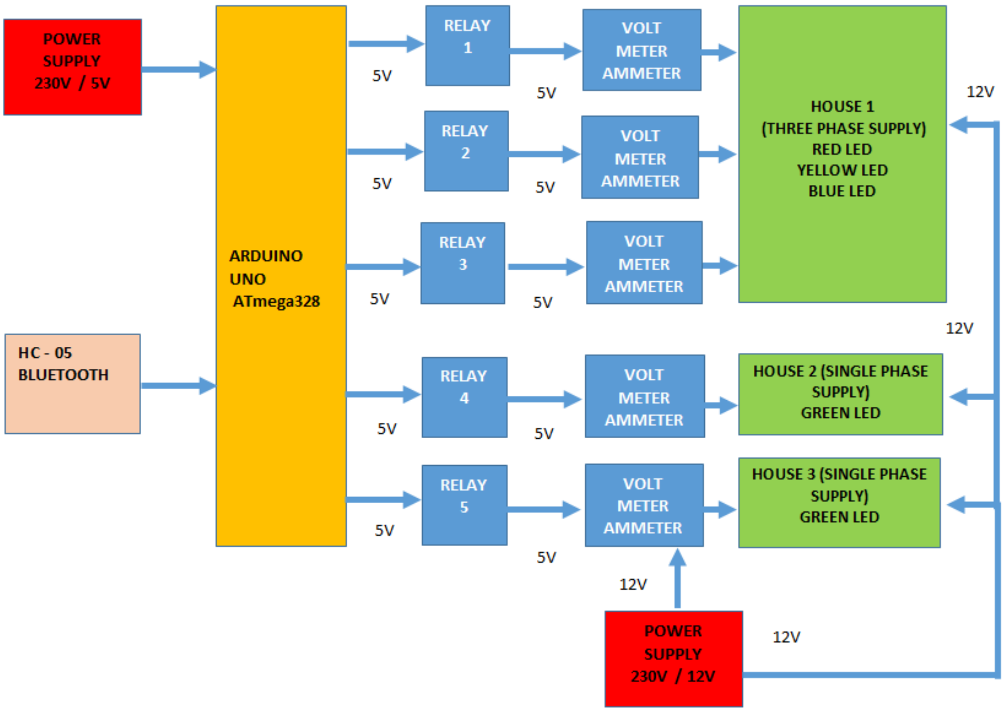
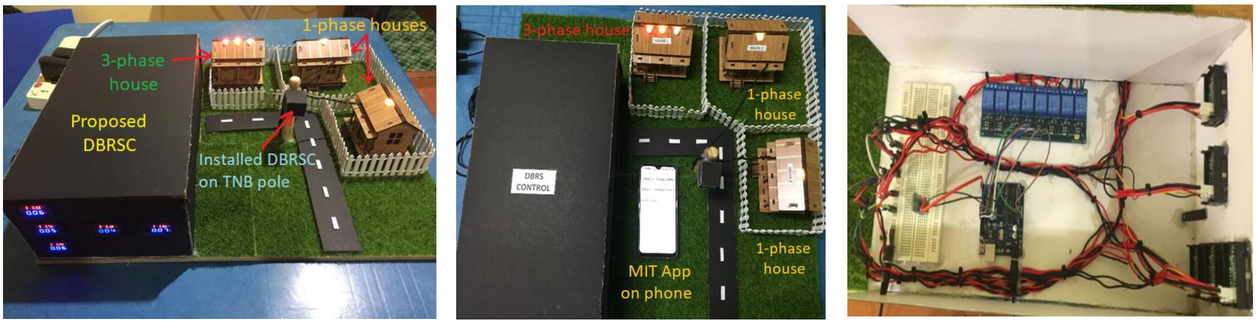


Figure 6. General Diagram of the Proposed Distribution Board Remote Switch Control (DBRSC)

4. Results and Discussions

Figure 7 shows the developed hardware of the proposed DBRSC system for TNB application. In the figure, the DBRSC box (black one), mobile phone showing the MIT App for designed DBRSC, the prototype of DBRSC box installed on a substation pole, single-phase houses and also a three-phase house are shown clearly. The live lights indicate the electrical system is operating normally.



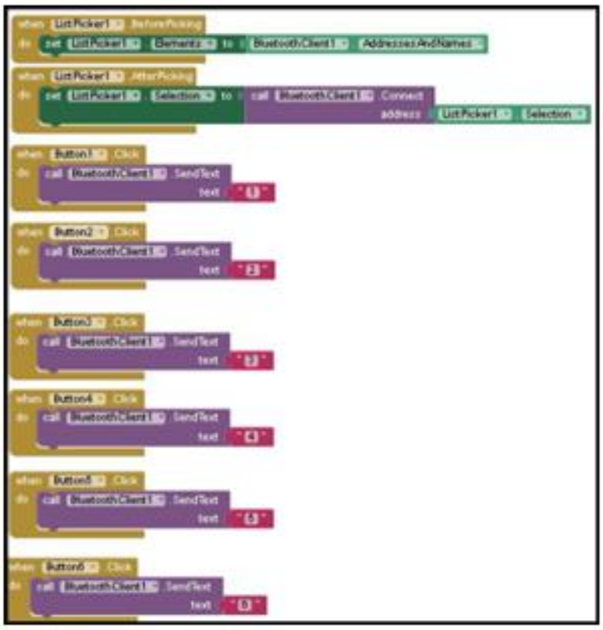
(a) Side View (b) Top View (c) Inside DBRSC

Figure 7. Developed Proposed DBRSC for TNB

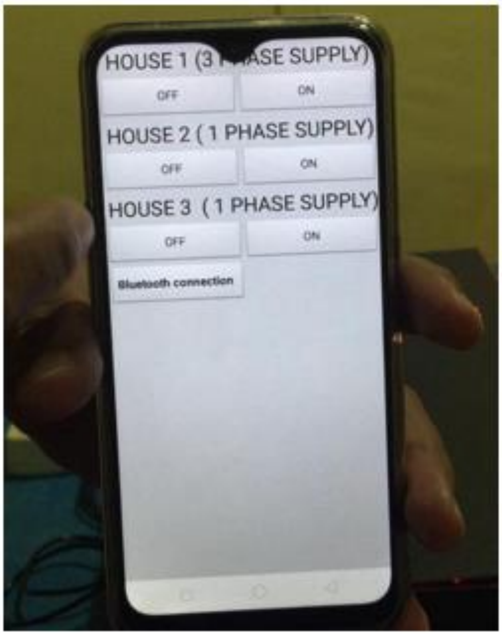
As shown in Figure 8(a), for single-phase system, only one LED bulb will light ON, indicates the house is operation in normal condition. Same goes to the three-phase house; all LED bulbs will be lighted ON to indicate each phase is supplied with the electrical power and operation in normal condition, as depicted in Figure 8(b) and Figure 8(c). All these LED bulbs will be OFF if the electrical connections are disconnected from the DBRSC box that supposedly installed on the substation pole. However, connections and disconnections can be done using MIT application installed in mobile phone. Meanwhile, in Figure 8(d), the readings of the houses' voltage and current are displayed on the installed LCD on the proposed DBRSC system. Figure 9(a) depicts the MIT App Inventor codes that have been written in the MIT App Inventor V3 software, while Figure 9(b) depicts the dashboard appearance on the MIT app.

(a) (b) (c) (d)

Figure 8. The Electrical Wiring in the Proposed DBRSC Box



(a)



(b)

Figure 9. (a) Coding written in MIT App Inventor V3 (b) Dashboard Appearance in MIT App

Table 1 shows the collected data on the LCD display of the proposed DBRSC box during the functional test. The voltage and current drawn on each phase for the single-phase and three-phase house are given, covering the ON and OFF state conditions. From the recorded data, it can be seen that the recorded data is relevant where each LED bulb requires 0.8 Watt to operate. Hence, the relation of voltage and current readings are proven when equation P=IV is used. As shown in the table, House 1 uses Relay 1, 2 and 3, while House 2 and House 3 uses Relay 4 and Relay 5, respectively for the switch control. All relays functioning very well. Using Arduino Uno, 8 pins are available for relay connections. However, for system that requires more than 8 pins, Arduino Mega is recommended.

Table 2 depicts the results on the signal coverage when the functional test of the proposed DBRSC system is executed when MIT Apps on mobile phone is placed between 0 to 60 meters. This then validated that the proposed DBRSC system functioning very well on Class 1 range which is signal can be transmitted up to 100 meters.

Table 1. The Electrical Wiring in the Proposed DBRSC Box

Component	MIT App V3		House	LED	Output							
					Voltage (V)				Ampere (A)			
	Position	Supply			Red	Yellow	Blue	Green	Red	Yellow	Blue	Green
Relay 1 Relay 2 Relay 3	ON	Three Phase	1	ON	11.8	11.5	11.8	-	0.06	0.05	0.06	-
	OFF			OFF	0.00	0.00	0.00	-	0.00	0.00	0.00	-
Relay 4	ON	Single Phase	2	ON	-	-	-	11.3	-	-	-	0.04
	OFF			OFF	-	-	-	0.00	-	-	-	0.00
Relay 5	ON	Single Phase	3	ON	-	-	-	11.6	-	-	-	0.04
	OFF			OFF	-	-	-	0.00	-	-	-	0.00

Table 2. Signal Coverage between Mobile App Phone and the DBRSC box

Distance (m)	Coverage
0 – 10	Good
10 – 20	Good
20 – 30	Good
30 – 40	Good
40 – 50	Good
50 – 60	Fail

In terms of energy consumption used to supply this DBRSC, this system uses 230V/5V for DC supply circuits and 230V single phase supply or 400V three phase supply for power supply to the user's home. The output voltage readings will be displayed according to the voltage and ampere used by the user. For example, every domestic household usually uses 20 amps based on consumer energy consumption. The DBRSC system can control 8 homes in one time, meaning energy consumption of 20 amps' x 8 homes is 160 amps per day. Since this power supply cutter uses switching method through a 250V AC relay rating that operates as a supply cutter and is operated via mobile phone, it is very friendly to be used. The use of this DBRSC system is very easy and quick when cutting off the electricity supply.

5. Conclusion

From the obtained results, it can be said that a simple, affordable but sophisticated Distribution Board Remote Switch Control (DBRSC) system has been successfully designed, developed and functioning very well when tested in the single-phase and three-phase distribution system. This proposed system has been tested in TNB environment working procedure in a success performance. Using this devise, the electricity disconnection on the fraud consumers who stole electricity and do not have intention to pay can be disconnected in easier and safely environment where the disconnection of the electrical circuit can be done by using mobile phone that was installed with the special MIT Apps for the proposed DBRS system. This app has been created using MIT App Inventor Software. The electrical disconnection can be done in 50 meters from the DBRSC box which supposedly mounted on the substation pole. Meaning that, TNB's staffs do not need to enter the fraud customers' premise or house areas to do the electrical disconnection. Special guards also no need anymore. It is therefore, as implication, TNB's staffs able to cut the electricity connection of the electricity thefts' premises and houses easier since the electrical connection can be switched off from the installed DBRSC on the substation posts in the streets. However, there numbers of recommendations that can be done in the future such as changing the type of relay with higher specification to enable more houses or premises can be controlled and managed simultaneously. Arduino Mega should be used as it has more output pins, hence more loads can be considered in the circuit. Lastly, RTU (remote terminal unit) SCADA system can be considered to replace the Arduino microcontroller for wider and high practical for energy management control.

Acknowledgment

The authors would like to express their appreciation for the support of the sponsors with Project No R.J130000.7351.4B687 and QJ130000.3051.03M49.

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