CHAPTER 2

THEORETICAL FOUNDATION

1.1 Theoretical Foundation

This chapter described some theories related to the monitoring of electricity consumption at home using cloud-based technology, which could promote greener IT. The related theoretical foundations related with the development of the application prototype and the cloud terms in more details. This chapter would also cover a little bit about electricity jargon to allow readers understand the topic clearer.

1.1.1 Application Software

Application software if seen from the delivery mechanisms can be classified into desktop and web applications. The software development itself first began with desktop applications, which could be used on standalone machines only. However, with the invention of Internet and online commerce, web application development began to gain importance. Microsoft Office can be considered as a typical desktop application, while an email accounts like Gmail on the website can be considered as a web application.

A brief explanation regarding the two will be discussed in the section below.

1.1.1.1 Traditional Desktop Application

By definition, according to PCMAG.com encyclopedia (n.d) a desktop application means any software that can be installed on a single computer (laptop or a desktop) and used to perform specific tasks [**6**]. Multiple users in a networked environment can also use desktop applications.

In general, desktop applications have the following characteristics:

- Targeted to a particular operating system.

  Usually using familiar user interface controls and have the same look and feel with the target operating systems

- Running on the local machine.

  Usually need to be installed on the local machine first before they can be used.

- Software programs that usually do not require the user to login before they can use it.

Desktop Applications have several advantages over web-based applications:

- Can run independently without depending on the browser.
- Does not need Internet connection because all of the required files are already installed in the local machine.

- Easy to modify the application's settings.
- Quicker process because both the data and the application reside on the same machine.

On the other hand, desktop applications also have several disadvantages, they are:

- Need to be installed first before being able to be used.
- Need to consider the software license which usually expensive.
- Sometimes need specific hardware requirement in order to run.

1.1.1.2 Web-based Application

Web based application is an application that can be run by using web technology or browser. This type of application can be accessed anywhere as long as there is Internet connection available. In conclusion web based application has these characteristics:

- Should be usable with any web browser running on any operating system
- The user interface controls can be different from the native operating system

- Hosted in a server, no additional software is needed or installed in the local machine
- Most of the processing system including data storage and business logic are handled by the server
- Usually need user login to access the system

The main advantages of web based application is that it can be run anywhere and anytime as long as there is browser and internet connection in which makes it very dependent from the internet in which can be considered as the main disadvantages from this type of application.

1.1.1.3 Cloud-based Application

Cloud application combines parts from desktop and web application to create something new. Just like the web application, the data lives in the cloud and like the desktop application the business logic reside in the web browser and lives there.

With this approach we have the best from both worlds. The application is accessible to anyone with web browser and at the same time all the interaction happens right next to the client. Although we cannot deny the

fact that the application runs over the internet, most of the time immediate response and rich interactions can easily be achieved.

Moreover cloud application makes it very easy to cache client's data locally, supporting full offline mode without posing a threat of security. Another benefit of this model is that it means the server will be smaller and simpler. More importantly as with any service exposed to the internet, server security needs to be considered as it will be used to authenticate requests and validate data. Cloud applications clearly offer a superior user experience to traditional web applications.

1.1.2 Cloud Computing

Today we have a new term called 'Cloud Computing'. The term Cloud Computing has become feasible for broad internet user in the last few years.

According to the survey conducted by CompTIA (2011) there is significant increase in understanding of cloud computing [7]. The graph of the result can be seen below.

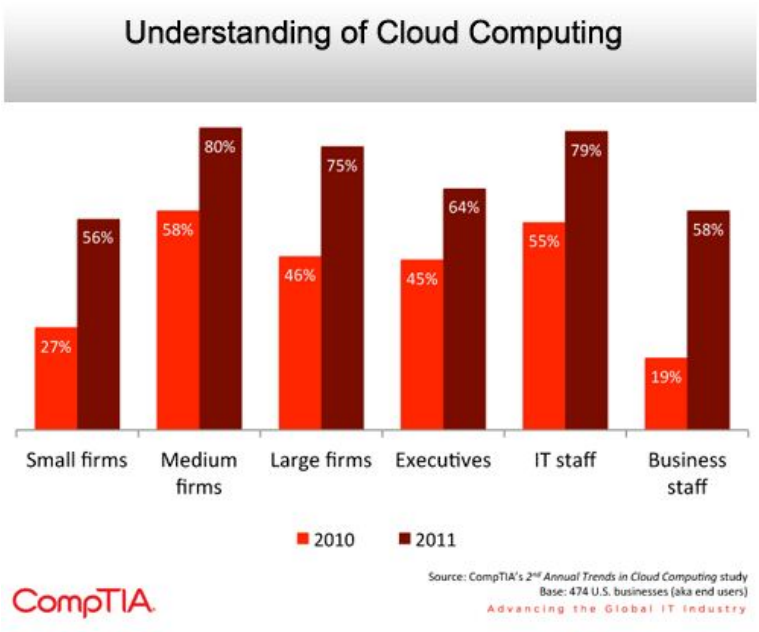

Figure 2.1 Trend of Cloud Computing

By looking into its abstraction level cloud computing services can be categorized into three classes i.e. Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS). We can also see this from the perspective of layered architecture where services from higher layer architecture can be comprised from services in the underlying layer.

1.1.2.1 Infrastructure as a Service

IaaS offers resource virtualization on demand (processing power, memory, storage, and bandwidth). This infrastructure allows on-demand monitoring of servers running different choices of operating systems and

a customized application stack. IaaS are considered to be the bottom layer of cloud architecture.

1.1.2.2 Platform as a Service

PaaS is considered to be in a higher level of abstraction compared with IaaS. Rather than providing infrastructure-based service Platform as a Service will be offering environment which will be suitable for developers who want to create and develop application without having to know the technical aspects of the system, how much the application will use. Moreover multiple programming languages and specialized services such as security, authentication, and payment gateway are provided as building blocks to new deployments.

1.1.2.3 Software as a Service

Applications are positioned on the top of the cloud architecture layer. Services that are presented by this layer can be accessed through the web portal. Therefore, many people start considering online software services rather than the locally installed computer programs, which offer the same functionally. Traditional desktop applications such as Microsoft office can now be accessed as a service in the Web (for example Google Docs). These services will ease the problem of software maintenance for the user

and simplifies software development including testing and implementation for vendors.

1.1.2.4 Deployment Models

The development of cloud computing is influenced by the presence of public computing utilities, while other factors suggest that variations in physical location and distribution will also play an important role. Based on these deployment models, cloud service can be categorized as private, public, community, or hybrid.

Armbrust et al. (2009) propose definitions for public cloud as a "cloud made available in a pay-as-you-go manner to the general public" and private cloud as "internal data center of a business or other organization, not made available to the general public" [**8**].

Setting up a private cloud can alter the existing infrastructure by adding cloud-like interface and virtualization. This enables the user to access local data center while having the advantage of public clouds, most importantly privilege access to the server, pay as you go billing, and self-service automated interface.

According to Mell and Grance (2009) a community cloud is "shared by several organizations and supports a specific community that has shared concerns (e.g., mission, security requirements, policy, and compliance considerations)" [**9**].

While Sotomayor together with Llorente and Foster (2009) said that if private cloud is equipped with the capacity of the public clouds, it will become hybrid cloud. The ability to temporarily renting capacity to handle jumps in load is known as "cloud-bursting". (Jaeger et al., 2009) [**10**].

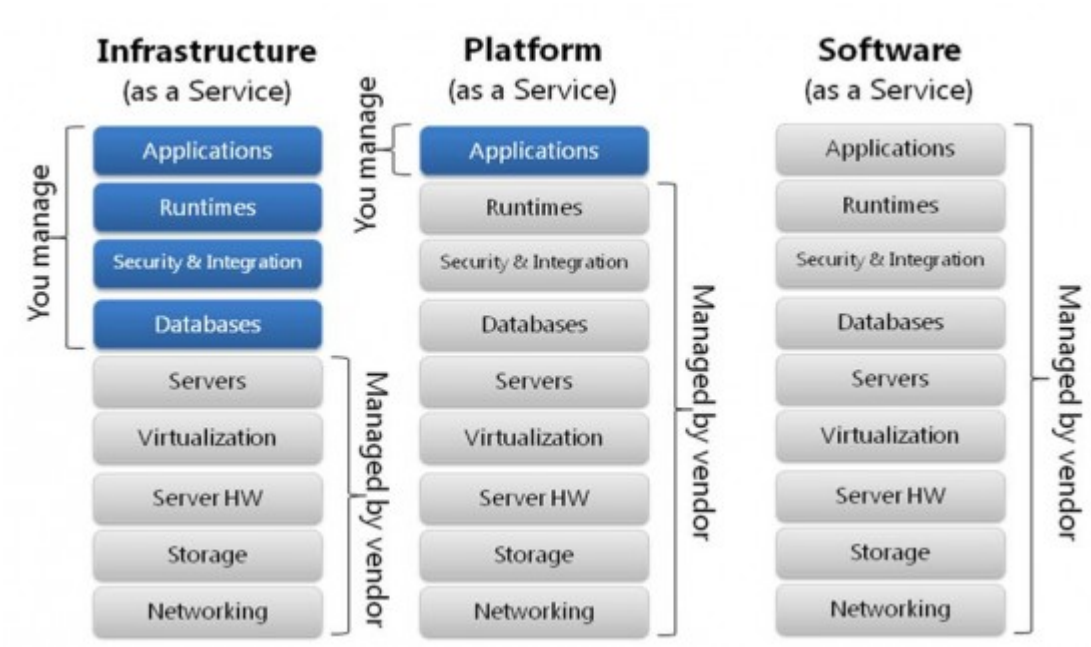

Figure 2.2 Comparison of Cloud Computing Type [**33**]

1.1.2.5 Features of Cloud Computing

There are certain features on cloud computing which allow services that surely will exhibit the cloud-computing model and fulfill the expectations of users, and cloud computing must be self-service, pay-as-you-go, scalable, and customizable.

1.1.2.5.1 Self-service

Consumers of cloud computing services expect on-demand, almost instant access to resources. In order to stand this supposition, clouds must provide self-service access so that users can inquire, tweak, pay, and use the service without interference from operators.

1.1.2.5.2 Pay-As-You-Go

Cloud computing eliminates in-advance obligation by users, granting them to inquire and use only what they need. Services must be billed on a short term basis, allowing immediate release of the resources as soon as they are not needed. Considering these, clouds must apply features that can provide efficient service such as pricing, accounting, and billing. Calculation should be done respectively for different types of service (e.g., processing power, memory, storage, and

communication) and report any usage immediately, thus providing greater transparency.

1.1.2.5.3 Scalability

Cloud computing gives the user a perception of infinite computing resources available on demand. Consequently users will expect clouds to be able to provide resources as soon as they are requested. In particular, it is expected that the additional resources can be provisioned, possibly automatically, when there is in an increase in the processing load and released when the load is starting to decrease.

1.1.2.5.4 Customization

In a multi-tenant cloud a great difference between user's demands could lead into problem. Thus, leased resources from the cloud must be able to be customized to accommodate user's needs. Each of the cloud service has different meaning of customization. In IaaS, customization means that users will be able to deploy specific appliances and have root access to the virtual servers. While SaaS and PaaS offer less flexibility in terms of customization and are not intended for general-purpose computing, both are still expected to allow certain level of customization.

1.1.2.6 Challenges and Risks

Regardless of the increasing popularity and initial success of cloud computing model and the extensive availability of vendors and tools, an apparent number of challenges and risks are inherent to this new model of computing. Vendors, developers, and end users must consider these challenges and risks to benefit from the advantage of cloud computing. Some issues to be addressed include security and privacy, data lock-in and service's availability, disaster recovery, performance, scalability, energy-efficiency, and programmability.

1.1.2.6.1 Security, Privacy and Trust

Security and privacy affect the entire cloud computing layer, since there is an extensive use of third-party services and infrastructures to host important data or to perform critical operations. In this scenario, the trust toward vendors or providers is crucial to ensure the desired level of privacy for applications hosted in the cloud.

Legal and regulatory issues also need to be addressed. When data are moved into the Cloud, vendors may choose to locate them anywhere on the planet. The physical location of data centers will affect the set of laws that can be applied to administrate the data. For example, different countries have different laws which forbid some technique to encrypt the data. Similarly, specific laws can also dictate that

sensitive data, such as patient health records, are to be stored within national borders.

1.1.2.6.2 Data Lock-In and Standardization

A major concern of cloud computing users is about having their data locked-in by a certain provider. Users may want to move data and applications from vendor that does not meet their requirements. Nevertheless, in their current situation, cloud computing infrastructures and platforms do not apply the same standard methods of storing user data and applications. Consequently, they do not interoperate and as a result portability will be compromised.

The solution to this problem is standardization. In this course, there are efforts to create open standards for cloud computing.

1.1.2.6.3 Availability, Fault Tolerance and Disaster Recovery

It is believed that users will have certain presumption about what service level they are going to get once their applications are moved to the cloud. These presumptions include the availability of the service, overall performance, and whether there are some actions to be taken when something goes wrong in the system or its

components. In conclusion, users seek for a warranty before they can comfortably move their business to the cloud.

Service Level Agreement (SLA), which includes Quality of Service specification, must be ideally set up between customers and cloud computing vendors to act as warranty. An SLA describes specific details of the service to be provided, including availability and performance guarantees. Additionally, metrics must be approved by all parties, and compensations for breaching the expectations must also be approved.

1.1.2.6.4 Resource Management and Energy Efficiency

One of the important challenges faced by vendors of cloud computing is how to manage the virtualized resource components efficiently. Physical resources such as number of processor, storage capacity, and network bandwidth have to be sliced and shared among users running virtual machine with possibly heterogeneous workloads.

Although mapping procedure of Virtual Machine onto available physical host will maximize user utility, the nature of virtual machine by being multi-dimensional somehow makes it difficult to be done.

There are number of dimensions need to be address that include CPU core, memory, storage space and bandwidth.

Dynamic Virtual Machines mapping policies may advantage the way of acquiring low-priority allocations in regards to higher ones that include the ability to suspend, migrate and resume the machine. Migration of VMs also creates additional challenges such as detecting when to start a migration, which VM to migrate, and where to migrate. Additionally, policies may benefit from live migration on virtual machines, for example the ability to split data center load without significantly disrupting running services. In this case, an additional concern will emanate on the benefits from live migration or the performance and stability impact from that migration.

Data centers consume large amounts of electricity. According to a data published by HP (2009), 100 server racks can consume 1.3MWof power and another 1.3 MW are required by the cooling system, thus costing USD 2.6 million per year. Besides as pointed out by Verma et al. (2008), the monetary cost, data centers significantly impact the environment in terms of CO2 emissions from the cooling systems [**11**].

In addition to optimize application performance, dynamic resource management can also improve utilization and consequently minimize energy consumption in data centers. This can be done by accordingly consolidating workload onto smaller number of servers

and turning off idle resources.

1.1.3 Programming Language

Below are the lists of programming language that the author uses in this research.

1.1.3.1 C / C++ Programming

C is a programming language originally developed for developing the UNIX operating system. It is a low-level and powerful language, but it lacks many modern and useful constructs. C++ is a newer language, based on C that adds many more modern programming language features that makes it easier to program than C language.

Basically C++ maintains all aspects of the C language, while providing new features to programmers that make it easier to write useful and sophisticated programs.

1.1.3.2 PHP

PHP (recursive acronym for *PHP: Hypertext Preprocessor*) is a widely used open source general-purpose scripting language that is especially suited for web development and can be embedded into HTML.

What distinguishes PHP from something like client-side JavaScript is that the code is executed on the server, generating HTML, which is then sent to the client. The client would receive the results of running that script, but would not know what the underlying code was. We can even configure the web server to process all HTML files with PHP.

The best things in using PHP are that it is extremely simple to use, but offers many advanced features.

1.1.3.3 MySQL

The MySQL database has become the world's most popular open source database because of its high performance, high reliability and ease of use. It is also the database of choice for a new generation of applications built on the LAMP stack (Linux, Apache, MySQL, PHP / Perl / Python.) Many of the world's largest and fastest-growing organizations including Facebook, Google, Adobe, Alcatel Lucent and Zappos rely on MySQL to save time and money powering their high-volume Web sites, business-critical systems and packaged software.

MySQL runs on more than 20 platforms including Linux, Windows, Mac OS, Solaris, HP-UX, IBM AIX, etc.

1.1.4 Layout and GUI

For the layout and GUI purposes, in order to deliver rich user experiences the author will mainly be using four technologies i.e. HTML, CSS, JQuery, and Ajax.

1.1.4.1 HTML

HTML stands for Hyper Text Markup Language. It is used to create a web page and it can integrate image, text and also interactive form.

1.1.4.2 CSS 3

CSS (Cascade Style Sheet) is W3C standard for defining the presentation of documents written in HTML, XHTML, and, in fact, any XML language.

1.1.4.3 jQuery

jQuery is a new kind of JavaScript Library. It is a fast and concise JavaScript Library that simplifies HTML document traversing, event handling, animating, and Ajax interactions for rapid web development

1.1.4.4 AJAX

Ajax is not a technology. It is really several technologies, each flourishing in its own right, coming together in powerful new ways. Ajax incorporates:

- standards-based presentation using XHTML and CSS;
- dynamic display and interaction using the Document Object Model;
- data interchange and manipulation using XML and XSLT;
- asynchronous data retrieval using XMLHttpRequest;
- JavaScript binding everything together.

1.1.5 Web Server

Web server helps delivering content that can be accessed throughout the internet. It can be a local webserver which is accessed on local computer or live webserver which is located on the Internet.

1.1.5.1 XAMPP

XAMPP is an easy to install Apache distribution containing MySQL, PHP and Perl. XAMPP is really very easy to install and to use - just download, extract and start.

1.1.5.2 phpMyAdmin

phpMyAdmin is a free software tool written in PHP intended to handle the administration of MySQL over the World Wide Web. phpMyAdmin supports a wide range of operations with MySQL. The most frequently used operations are supported by the user interface (managing databases, tables, fields, relations, indexes, users, permissions, etc), while still being able to directly execute any SQL statement.

1.1.5.3 Microsoft Windows Azure

Windows Azure is cloud platform in which user will be able to build, deploy and manage application across Microsoft datacenters in a flexible and efficient manner. Windows Azure currently supports Java, PHP, .net, and python.

1.1.6 Integrated Development Environment (IDE)

There were two main IDE components that the author used to develop the system prototype. They were:

1.1.6.1 Netbeans 7.0.1

NetBeans is an open-source integrated development environment available for Windows, Mac, Linux, and Solaris. The NetBeans project consists of an open-source IDE and an application platform that enable developers to rapidly create web, enterprise, desktop, and mobile

applications using the Java platform, as well as PHP, JavaScript and Ajax, Groovy and Grails, and C/C++.

1.1.6.2 Arduino IDE

Arduino IDE was used to code and upload it to the board microcontroller. The IDE itself was written in Java and based on Processing, avr-gcc and other open source software. It is available both in Windows and MAC version.

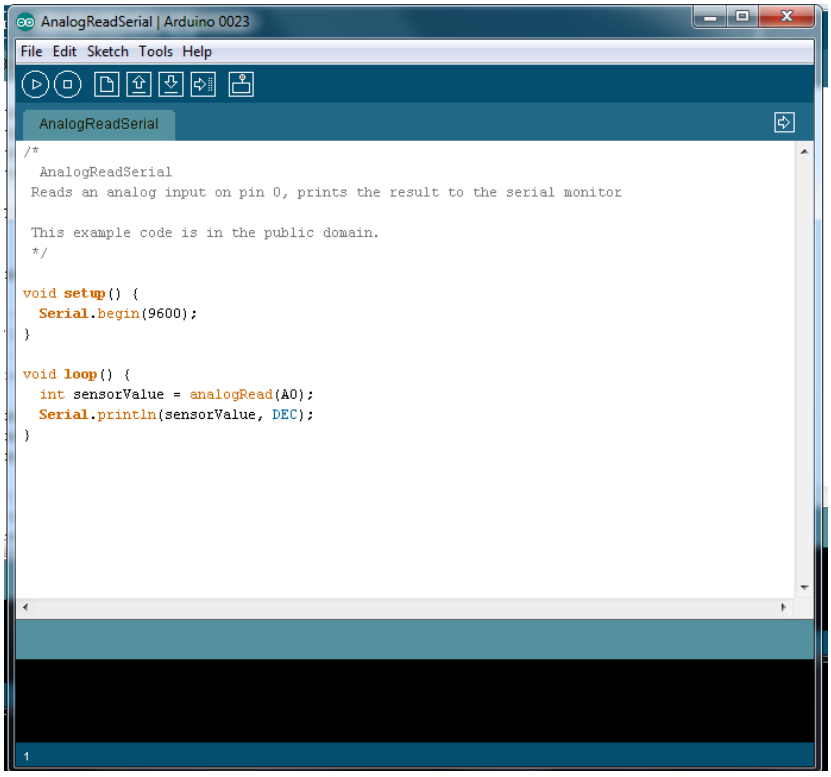

Figure 2.3 Arduino IDE

1.1.7 Arduino Platform

Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software.

Arduino can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors, and other actuators. The microcontroller on the board is programmed using the Arduino programming language (based on Wiring) and the Arduino development environment (based on Processing). Arduino projects can be stand-alone or they can communicate with software running on a computer (e.g. Flash, Processing, MaxMSP).

The Arduino board's microcontroller needed to be programmed in order for the board to be able to capture the current usage from the input pin. The programming was done using Arduino IDE, which could be downloaded from the arduino website and it could be programmed using high level language C++, so we did not need to concern with all the difficult machine / assembly language.

The board was connected to the computer using FTDI cable which could also act as a power source for the board so we did not need to put the battery when we connected it to the computer.

1.1.8 Current Transformer

Current transformers (CTs) are an indispensable tool to aid in the measurement of AC current. They provide a means of scaling a large primary (input) current into a smaller, manageable output (secondary) current for measurement and instrumentation.

Figure 2.8 Current Transformer

A CT utilizes the strength of the magnetic field around the conductor to form an induced current on its secondary windings. This indirect method of interfacing allows for easy installation and provides a high level of isolation between the primary circuit and secondary measurement circuits. CTs are available in various sizes, designs and input ranges and output signal types.

This application note will attempt to address many of the common CT types, and how to select the correct CT for a particular installation.

A CT is useful for measurements made on AC waveforms. It acts just like a regular voltage transformer, but typically has only one primary winding (the wire carrying the current to be measured). Unlike a regular voltage transformer, there is no physical connection made to the measured line.

The CT uses magnetic fields generated by the AC current flowing through the primary wire to induce a secondary current. The ratio of the number of secondary turns to the number of primary turns determines the amplitude of the current on the output. The output of a CT acts as a current source.

1.1.9 How We Measure Electricity

According to Merriam-Webster dictionary the world electricity can be defined as

"A fundamental form of energy observable in positive and negative forms that occurs naturally (as in lightning) or is produced (as in a generator) and that is expressed in terms of the movement and interaction of electrons. (Merriam-Webster dictionary, 2011) [**12**]"

James Clerk Maxwell (1891) has different view on the word electricity. He said that the word electricity and electric charge are used interchangeably and that electric currents are flow of electricity therefore it can be measured and marked by ‘e’ [**13**].

Put it in our term, electricity is a term used to describe the energy produced when there is a flow of electric charge through a medium. The charge is caused by the movement of electrons between atoms called electrical current.

The term ‘measure electricity’ can be presumed as measure of electric current. It is very important to be able to measure and estimate the flow of electric currents.

1.1.10 Power

There are three different of powers.

1.1.10.1 Active Power

Active power is often defined as the power used by a device to produce useful work. The power that was actually used by the load the power going to minus the power going back is the real power.

1.1.10.2 Reactive Power

Reactive power is a measure of the power going back from the load to the supply.

1.1.10.3 Apparent Power

Another useful measure of power is Apparent Power which is the product of the Root-Mean-Squared (RMS) of the Voltage and the RMS of the Current. For purely resistive loads real power is equal to apparent power. But for all other loads real power is less than apparent power. Apparent power is a measure of the real and reactive power but it is not a sum of the two, as the sum of the two does not take into account phase differences.

Relationship between real, reactive and apparent power (AP):

Real Power = AP x cos φ

Reactive Power = AP x sin φ

cos φ is the power factor.

1.2 Research Methodology

In this research the author is going to use different kinds of approach to finally come up with the solutions.

The author will have a regular meeting with the supervisor to seek for guidance in developing this research.

An interview will be done with one of the engineering from PLN Indonesia to see how the KWH meter in our home works.

Develop the system according to the specifications.

Implement and test the system in real life environment to see how it works.

Analyze the data and see if there is any benefit from developing the system.