ERROR CORRECTION FOR TEBA APPLICATION IN A BUILDING MANAGEMENT SYSTEM

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Degree of Master of Science

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Sri Lanka

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Thesis submitted in partial fulfillment of the requirements for the degree Master of Science

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Finally I wish to thank my parents and my wife for unwavering and resolute support given while this dissertation is being prepared.

ABSTRACT

Every increase in the unit cost of Energy just magnifies the importance of conserving energy and can't accomplish that without tracking its use. More than ever, sub-metering is being applied in industrial as well as the traditional commercial and residential applications to encourage conservation and increase productivity. Smart Energy monitoring & Billing is new concept in the word and near future need the requirement & regulations for the smart Energy Billing for smart Building Owner and Tenant Energy User.

Smart Energy monitoring & Billing is new concept for Sri Lanka and near future need the requirement & regulations for the smart Energy Billing. In Present many of the countries in the word are decided to intended regulations for commercial building & other energy consumers in their country.

Although sub-metering can be used to perform most critical functions such as equipment monitoring, trending, alarming, predicative maintenance, communication, and power quality analysis. This research will concentrate on Tenant billing of the Energy.

Cooling Energy billing is one of the particular areas of the energy billing in commercial building sector Including Electrical Energy Usage, Cooling Energy Generation, and Cooling Energy Distribution & Tenant Side Air Handling Unit Energy Consumptions.

The thesis is based for identification of existing billing method for cooling Energy billing and introduced new strategy for chilled water cooling energy billing system. Using existing building energy billing system one month period real time energy data and mathematically functions analyzed new algorithm for error correction. In this error correction algorithm introduced estimation method for cooling energy loss & stored energy in the chilled water piping System. The data simulation for the new method the existing energy billing error reduced around 50% of existing real time energy billing system. That strategy application of chilled water energy billing system be more smart Billing for tenant & building owner.

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LIST OF ABBREVIATIONS

Abbreviation	Description
A	Ampere
AC	Alternative Current
AC	Air Conditioning
AHU	Air Handling Unit
AMR	Automated Meter Reading
BAS	Building Automation System
BMS	Building Management System
BTU	British Thermal Unit
CDD	Cooling Degree Day
CPP	Cost per person
CT	Current Transformer
DC	Direct Current
DCS	District Cooling System
DDC	Direct Digital Controller
E	Total Electrical Energy Input to the Central AC Plant
EBI	Enterprises Building Integrator
EIS	Energy Information System
E_r	Total electrical energy input to the AC Plant in *kWh.*
e_r	Total electrical energy input to the AC Plant in *kWh*
HDD	Heating Degree Day
IP	Internet Protocol
IT	Information Technology
kWh	Kilo Watt Hour
LAN	Local Area Network
m/s	Meters per second
mA	Mille Ampere
MF	Maintenance Factor

Q_b	Balanced Cooling Energy in the System
Q_h	Heat flow rate in kW
Q_i	i^{th} AHU Consumed Energy
Q_p	Chiller Generated Cooling Energy
Q_r	Total Cooling load for AC Plant (Zone 1 & 2) only for time t in kW.
Q_S	Stored Cooling Energy of the System
Q_T	Total refrigererent tons generated at the AC plant
Q_t	Total refrigererent tons used by tenant AHU
R	Rate of change for Electricity *Rs/kWh.*
RF	Radio frequency
RTU	Remote Terminal Units
SCADA	Supervisory Control and Data Acquisition
SQL	structured query language
SS	Stainless Steel
TCP	Transmission Control Protocol
TEBA	Tenant Energy Billing Application
$\boldsymbol{TEB_t}$	Tenant Energy Bill
VA	Volt Ampere
WAN	Wide Area Network

LIST OF APPENDICES

1. INTRODUCTION

An “advanced meter” is commonly considered an energy meter that provides short interval measurements and can be read remotely. The term “smart meter” is also used but generally refers to meters with the capability to send and receive messages regarding pricing, along with other sophisticated utility functions.

Tenet Energy Billing Application (TEBA) refers to a feedback where advanced meters, remote database storage and software tools are employed to monitor and maintain energy billing application in a commercial Building.

The TEBA collects energy consumption data from Building Management System on a continuous basis to provide feedback to Property Management Teams, operators and Tenant users who maintain and improve performance through equipment & Monthly Energy Rates & Charges. TEBA System and features are deployed at different levels (i.e. whole building, or component) depending on the size and complexity of the building. Significant advantages over reliance on utility bills for performance feedback include:

- Automatic billing for Tenant utility (Water, Electricity, Chilled water, hot water, etc).
- Much easier and more reliable access to energy usage information for portfolio managers, designers, energy efficiency programs and energy service consultants.
- Immediacy of information, compared to waiting for bills to arrive at fixed intervals.
- Additional detail (daily, hourly, sub-metering where desired), facilitating further investigation into problems and tenant usage allocations.

1.1 Level of the TEBA System

The advanced meters that form the TEBA can be installed to monitor any Energy used in commercial buildings including natural gas, electric, fuel oil, heated or chilled water, or steam. The most common Energy for commercial buildings are electricity & Chilled water cooling Energy.

The installation and use of a TEBA can involve measurements at different levels of the building, referring to what energy end-uses are captured in the measurement. Following basic installation levels are commonly available for the TEBA Systems.

1. Whole Building, premises or site: The advanced meter measures usage for the whole site including all systems, components and auxiliary loads. Installation may be by the owner or the utility.
2. System or Subsystem: The meter measures the energy usage of a certain type of equipment installed in the building (e.g. lighting, elevators, heating, cooling, core and shell, tenant sub metering). sub metering installed to allocate the utility bill among tenants is considered system level metering in this report.
3. Component or Equipment: The owner-installed meter measures the input to a single piece of building equipment, such as a boiler or chiller. Often this metering is combined with other of building equipment, such as a boiler or chiller. Often this metering is combined with other output as Electrical Power Meter data, Thermal Energy Consumption Data etc.

1.2 Type of Energy or Utility Billing Available

Many buildings are equipped with only a primary metering system for measuring and billing energy consumption for the entire building. In buildings with this configuration, the tenants are typically billed for energy usage on either a fixed rate (cost per square foot) that is built into the lease, or the bill is allocated to tenants based on their square footage. Each of these methods have inherent flaws, but both share the common problem that energy costs are unlikely to be accurately charged to the tenants. Under a cost per square foot arrangement, the owner will almost certainly collect more or less than the actual bill, and the discrepancy will be even greater during times of energy volatility or low occupancy rates. If the bill is simply divided amongst the tenants on a per square foot basis, tenants with lower energy density (BTU per square foot) will subsidize the space costs for those with higher energy density (e.g., data centers). These errors become particularly acute when there is a wide variance in occupancy schedules (retail vs. office space) and the building provides central services such as chilled water or conditioned air. Additional complexity is added when the building owner must make decisions in advance on the cost to add when the rate structures for commercial buildings are taken into account.

1.3 Survey of Utility Rates

When Analysis of Utility Rate Structures can be identified various type of billing strategy & Structures available in the world. The following parameters define the characteristics of rate structures from different perspectives:

- Price trigger:
    - Time trigger (price period): seasonal rate, monthly rate, daily rate, time of use, and real-time pricing.
    - Event trigger (price event): CPP-fixed, CPP-variable, direct load control, interruptible rate, load curtailable rate, demand bidding, demand buyback, extreme day pricing.
- Range of price period:
    - Season: seasonal rate
    - Month: monthly rate
    - Day: daily rate o Hours: daily time of use
    - Hour or less: real-time pricing
- Price dynamics during price period:
    - Fixed price: energy rate, energy and demand rate, time of use.
    - Fixed price + spot price: two-part real-time pricing.
    - Spot price: one-part real-time pricing.

- Range of spot price
  - Upper bound: real time pricing with caps.
  - Upper and lower bound: real-time pricing with collars.
  - Unbounded: real-time pricing.
- Advance notification of price event
  - Day ahead: real-time pricing
  - Day of: real-time pricing
  - Day after: daily pricing (Portland General Electric)
  - Hour ahead: real-time pricing
  - Half hour ahead
  - No notification: interruptible rate, direct load control.
- Frequency of price even
- Duration of price event
  - Fixed hours: critical peak pricing - fixed, extreme day pricing,
  - Variable hours with upper bound: critical-peak pricing - variable, direct load control, interruptible rate, demand bidding, demand buyback.

Price dynamics during price event

- Fixed price: critical peak pricing, extreme day pricing, direct load control, interruptible rate.
- Spot price: market-based interruptible rate, demand bidding, demand buyback.

1.4 Motivations for Increased Advanced Metering Systems in the world

Increasing the energy cost and energy management in the world the energy users motivated to monitoring and analyzing their energy consumption. Mainly their motivations are based on,

Persistence in Building Efficiency: Achieving and maintaining the performance of highly efficient buildings will require effective monitoring with owner/operator feedback.

Evidentiary Design: There is little hard evidence of verified building performance; a 2007 study of LEED buildings1 carried out by New Buildings Institute showed wide variation in predicted versus actual energy usage. For future buildings to improve, simpler and faster data collection methods are needed to acquire this critical feedback and proof of performance.

Advancing Building Performance Metrics: It's likely that the next generation of energy codes and building programs like LEED will call for performance requirements. Building Performance Review and labeling programs will necessitate separation between tenant activity-driven loads (such as plugs) and processes and the core and shell loads (such as HVAC and common area lights) and require flexible metering and data acquisition.

1.5 Objective of the Research

This research is designed to help regulators, program managers and other interested parties understand the error corrections available in advanced **metering** as used in tenant energy billing system Applications (TEBA) for sub metering in centralize Chilled water plant with Chilled water distribution systems in commercial building or District Cooling System (DCS).

1.6 Motivation of the Research

With incising the trend of Enterprises Energy management systems and green building technologies in Sri Lankan building sectors also interested to Integrated Cooling Energy billing systems with their building Management systems. The HNB Bank Head office tower building is 1st and only building that installed TEBA Integrated cooling energy billing systems in Sri Lanka.

The system is based on real time cooling energy balancing for the cooling energy billing in 6 min time intervals. But considering the energy difference between cooling energy production of the chiller plant and cooling energy consumption of the Air Handling units is nearly 8 to 9% of the cooling energy production of the day. That is actually uncomfortable satiation for Building Owner and the tenant. This situation is effect to discourage the industry to install the TEBA systems their buildings.

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2. TEBA SYSTEM ARCHITECTURE

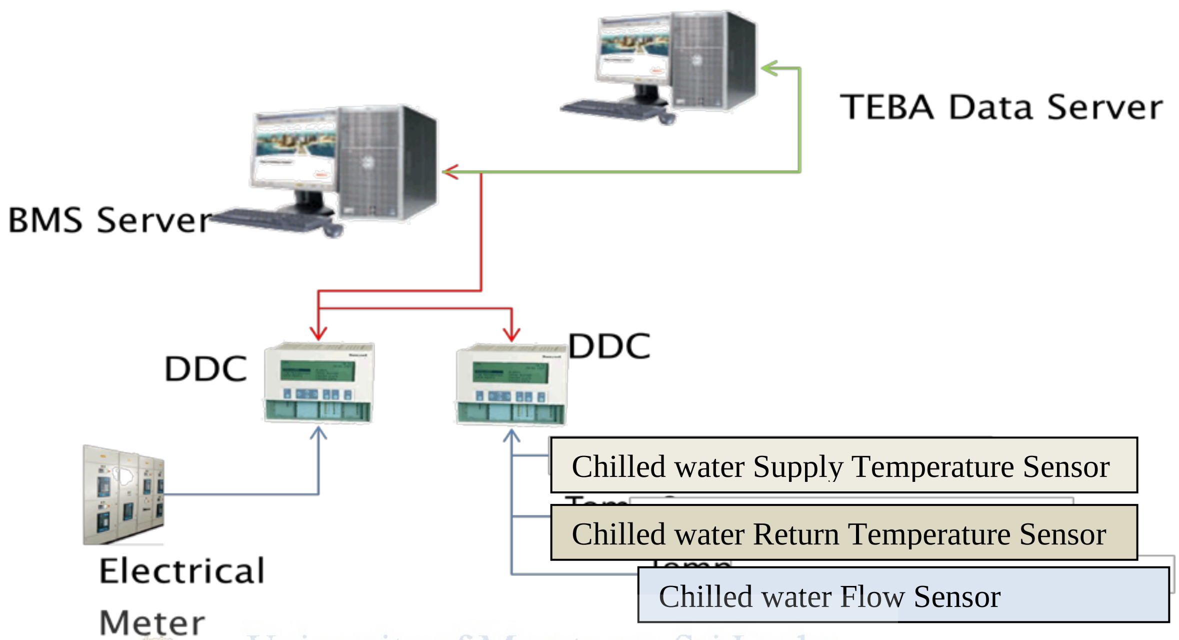

Figure 2.1: TEBA System Architecture

2.1 Building Management System (BMS) Server

Building Management System Server is the Management Level Processors, at the top of the BAS system hierarchy, exercise control and management over the connected subsystems. An Operator at this level can request data from and issue commands to point anywhere in the system(as which most operations –Level processors).Day to day operation is normally a function of the operations-Level processor; However ,complete control can be transferred to management level processor during the emergencies or unattended periods. The management-level processor primary collects, stores, and processes historical data such as energy use, Operating costs and alarm activity, and generate reports that provide a tool for the long term management and use of the facility.

When using multiple operation/management level processors, one is defined as the database server, where current database resides. Any processor may initiate a system change (graphic or text modification, operator assignment, schedule, etc), but all changes are made to the server database. The server is a software function and may be a dedicated Computer or any other LAN processor.

2.2 TEBA Data Server

2.2.1 Data Storage Software

Assuming proper data collection and communication, some form of data storage system will be needed for the TEBA System development. The data storage needs will depend on the number of meters connected, the number of parameters metered, the data interval, and the expected need for access to historic data. In most cases, one of any number of commercially available database software systems will function well for data storage and software interface. The specific requirements of the data storage/database system should be decided with assistance from site IT staff or others knowledgeable, or those who will be using the system.

2.2.2 Data Storage Specification Considerations

Data for the TEBA shall be stored in a structured query language (SQL) compliant database format or time series format. Minimum requirements are a SQL server or equivalent. The database shall allow other application programs to read and access the data with appropriate password protection while the database is running. The database shall not require shutting down in order to access or have data added.

Trend data shall be archived in a database from field equipment in time intervals no less than once per day. Storage on the field equipment will be reset once data are exported to allow for trending if communication is disrupted. Data will be uploaded once communication is re-established.

Blank or null values in the database will be replaced with actual data using past recorded data or manually feed data to the system. Calculations and other metrics will be updated once controller data is uploaded. This overall system update to check for new data should be automated to run once a day.

All data shall be stored in database file format for direct use by third-party application programs. Sufficient data storage capacity will be able to store at least two years of data for all data points. In addition, storage capacity will also allow for compression of one year of data for historic trends and archiving.

Time stamps shall be collected on all data. The time stamp, depending on system architecture, will be captured at the field controller or system controller and directed to the database archive.

Exported data shall contain no duplicate records or duplicate time stamps in output files. Each date/time stamp for a specific point shall be unique. The export query shall be for a specific point or multiple points in a defined group.

Date/Time fields shall be in a single column in a format automatically recognized by common spreadsheet, database software tools, or EIS.

The data shall be fully contained in a single file or table for each point. Data shall not span multiple files or database tables. Users can have the option to modify export file start and end file date span depending on third-party program requirements to evaluate the data. Key to productive use of data is the access for analysis, whether done in-house or as part of a third-party EIS package or agreement.

2.3 Data Storage Hardware

The computer hardware for data storage and software execution should have ample processing power and memory to run the chosen database system and to process, store,

and archive all collected data. Fortunately, such activities can be handled quite easily with modern stand-alone personal computers and/or workstations. One key recommendation is that whatever system is chosen, it be dedicated to this activity. It is also recommended that this system have an automated back-up function (typically daily) to a separate system/server for data protection and archiving. An increasingly popular option for data storage involves an agreement with a third-party organization (e.g., an EIS vendor or other data-hosting entity)
whereby all data are collected, stored, and backed-up on vendor computer servers. In this case, the client is given access, usually over the web, to all data and analyses for addition processing, reporting, and downloading.

2.4 Direct Digital Controller (DDC)

DDC is a types of microprocessor-based controllers used in commercial buildings. These controllers measure signals from sensors, perform control routines in software programs, and take corrective action in the form of output signals to actuators. Since the programs are in digital form, the controllers perform what is known as direct digital control (DDC). Microprocessor-based controllers can be used as stand-alone controllers or they can be used as controllers incorporated into a building management system utilizing a personal computer (PC) as a host to provide additional functions. A stand-alone controller can take several forms. The simplest generally controls only one control loop while larger versions can control from eight to 40 control loops. As the systems get larger, they generally incorporate more programming features and functions. This section covers the controller as a stand-alone unit. Refer to the Building Management System Fundamentals section for additional information on use of the controller in networked and building management systems.

2.5 Metering Communications and Data Storage

An integral part of the overall metering system is the mode of communications from the sensors to the meter and then from the meter to the point of data storage, analysis, and archiving. The communication from sensor to meter is usually handled internal to the meter and largely transparent to the user. The communication from the meter to the ultimate storage, analysis, and archiving is the focus of this section. Regardless of the meter type, once data are collected they need a communication pathway to a location where the data will be processed, stored, and used. This pathway should be amenable to the various meter output types – some of the more common output types include:

- Analog output – typically, 4 to 20 mA or 0 to 5 volts dc
- Contact closure – pulse type output
- Digital output – digital pulse
- Digital signal – outputs using networked communications (e.g., Ethernet, Modbus, HART).

Many of the newer digital-signal output meters can output multiple signal types offering a variety of communications options. These meters can be serially addressed, affording a lowered installed cost through reduced wiring installation and expense (i.e., multiple meters communicating on one pair of wires back to the data-collection terminal). Often these outputs can be viewed on local displays integral to the meter. These displays are quite useful for field set-up, calibration, verification of function, and troubleshooting.

2.6 Traditional Metering Communication Communications Options (Non-Automated)

Over the past 20 years, communications have moved from requiring a hand-written recording of the metered value to a manually entered electronic recording to a locally transmitted electronic value. These data collection/communications modes are still in practice and are described below.

2.6.1 Sneaker-net Data Collection.

A largely outdated, yet still practiced, method of manual meter reading involving writing down or keying in to a hand recorder the metered data. This data collection practice is inefficient, inaccurate, and discouraged in most applications.

2.6.2 Mobile-Radio Data Collection.

This technology makes use of close-proximity radio frequency (RF) communications where by data are transmitted by the meter to a receiver – usually located in a slowly moving vehicle. While more accurate than sneaker-net, it still has an in-field manual collection component – driver and vehicle.

With the enactment of EP Act 2005, which explicitly states that metered data will be collected automatically, via automated meter reading (AMR) and made available at least daily, federal agencies are now required to use AMR – where practicable. As such, the following section presents the AMR systems that are more common and applicable to the federal sector.

2.7 Modern Metering Communications: Automated Meter Reading (AMR)

AMR systems, both wired and wireless, are increasingly being used owing to their availability, reliability, and decreasing cost. Many utilities, large corporate campuses, and universities are finding AMR not only to be convenient, but to make good business sense. When developing the communications portion of your metering program, it is important to consider what existing communications infrastructure you can take advantage of (e.g., building automation system, local area network) to potentially lower the cost of AMR. In addition, if you have a large site with distributed buildings you may find benefit in considering multiple communications technologies (e.g., networks in one area, phone lines in another, and wireless in a third) to gain the necessary communications coverage. Below are the predominant AMR technologies along with some of the benefits and challenges of each.

2.7.1 Phone Modem.

Taking advantage of telephone modem technology in both hardwire and wireless (i.e., cellular), this communications solution is the oldest and traditionally most reliable of the technologies. In typical applications, automated software (usually from the metering equipment vendor) is used to dial (phone-in) the modem daily to retrieve accumulated data. In addition to the phone-in systems, there are meters that can phone-out at preset times or at specified data accumulation levels. It should be noted that phone lines do not have to be dedicated to the meter(s) they serve; there is no reason meters cannot share a phone line with other applications – even personal office phones. Shared phone line applications can use off-hours for data communications and, therefore, do not interfere with other business-related uses.

2.7.2 Local Area Network.

Using an existing building or site's computer network to serve as the communications path for the metering system can be very economic. When properly configured, meters can communicate over this network using a variety of open protocols, including Modbus, HART, TCP/IP, BACnet, etc. In addition, these meters usually can be serially addressed and linked together (daisy-chained) to minimize wiring installation and expense.

Beyond the local area network (LAN), wide-area networks (WANs) can be developed by linking more than one of these networks together (usually via phone lines or through wireless solutions). This becomes useful to large sites with many distributed buildings and locations. Additional benefits to the LAN solution include the ability to share data throughout the network and view data in real time. Prevalent concerns with using a LAN for data communications stem from perceived security issues with transferring data over secure networks and potential access to the LAN via the metering points. In both cases, these concerns can be addressed with typical LAN security protocols. As is often the case, some level of education on the system, its operation, and security may be necessary – a small demonstration of the system may help convince skeptical IT or information-security staff.

2.7.3 Radio Frequency/Wireless Networks.

Becoming increasingly available and economic, wireless radio frequency (RF) communications makes use of wireless transmitters and receivers to communicate metered data. Wireless communication (FEMP 2007) offers the benefits of lowered installation cost, flexibility in metering locations, and minimizes disruption in service when compared to other options. Some of the limitations to wireless communications include the effective distance of communication (typically less than 300 feet) and the building's materials of construction that may impede or block the RF signal. Both situations can be mitigated by using a repeater or mesh network configuration. Similar to the LAN solution, wireless communications has perceived challenges including security issues and potential for interference with other sensitive communications equipment. In many cases these concerns are unfounded, yet some level of education on the system, its operation, and security may be necessary – a small demonstration of the system may help convince skeptical IT or information-security staff.

2.7.4 Power Line Carrier.

This technology uses existing electrical wiring, both internal and external to buildings, as the communications conduit. While making use of the existing infrastructure gives this technology and economic advantage, some of the limitations relate to speed and quantity of data transfer and the ability to transfer data across standard electrical transformers. Organizations making productive use of this technology, notably utilities and sites with many distributed buildings, do so by spreading the considerable installed cost over many metering points.

2.8 Building Automation System.

By using an existing Building Automation System (BAS), we again take advantage of a site's previous investment in existing infrastructure. In this case, the wiring used for BAS communication becomes the metering communications path. In this case, the meters are treated as other "points" on the BAS and function much as other sensors or points on the system (i.e., communicate to and from the central host computer). The BAS is a workable solution only when there is excess capacity to add points and system software is capable of using the meter's data output protocol – both of these factors need be verified with the BAS and metering equipment vendors. An additional constraint to the BAS solution relates to the host computer's ability to allocate memory for these data and offer an ability to retrieve data sets in an automated fashion.

2.9 Data Storage Software

Assuming proper data collection and communication, some form of data storage system will be needed. Data storage needs will depend on the number of meters connected, the number of parameters metered, the data interval, and the expected need for access to historic data. In most cases, one of any number of commercially available database software systems will function well for data storage and software interface. The specific requirements of the data storage/database system should be decided with assistance from site IT staff or others knowledgeable, or those who will be using the system. Below are draft specifications based on work done for the California Energy

Commission Public Interest Energy Research Program and the Building Technologies Program of the U.S. Department of Energy (CEC 2007).

2.9.1 Data Storage Specification Considerations

Data shall be stored in a structured query language (SQL) compliant database format or time series format. Minimum requirements are a SQL server or equivalent. The database shall allow other application programs to read and access the data with appropriate password protection while the database is running. The database shall not require shutting down in order to access or have data added. Trend data shall be archived in a database from field equipment in time intervals no less than once per day.

Storage on the field equipment will be reset once data are exported to allow for trending if communication is disrupted. Data will be uploaded once communication is re-established. Blank or null values in the database will be replaced with actual data. Calculations and other metrics will be updated once controller data is uploaded. This overall system update to check for new data should be automated to run once a day.

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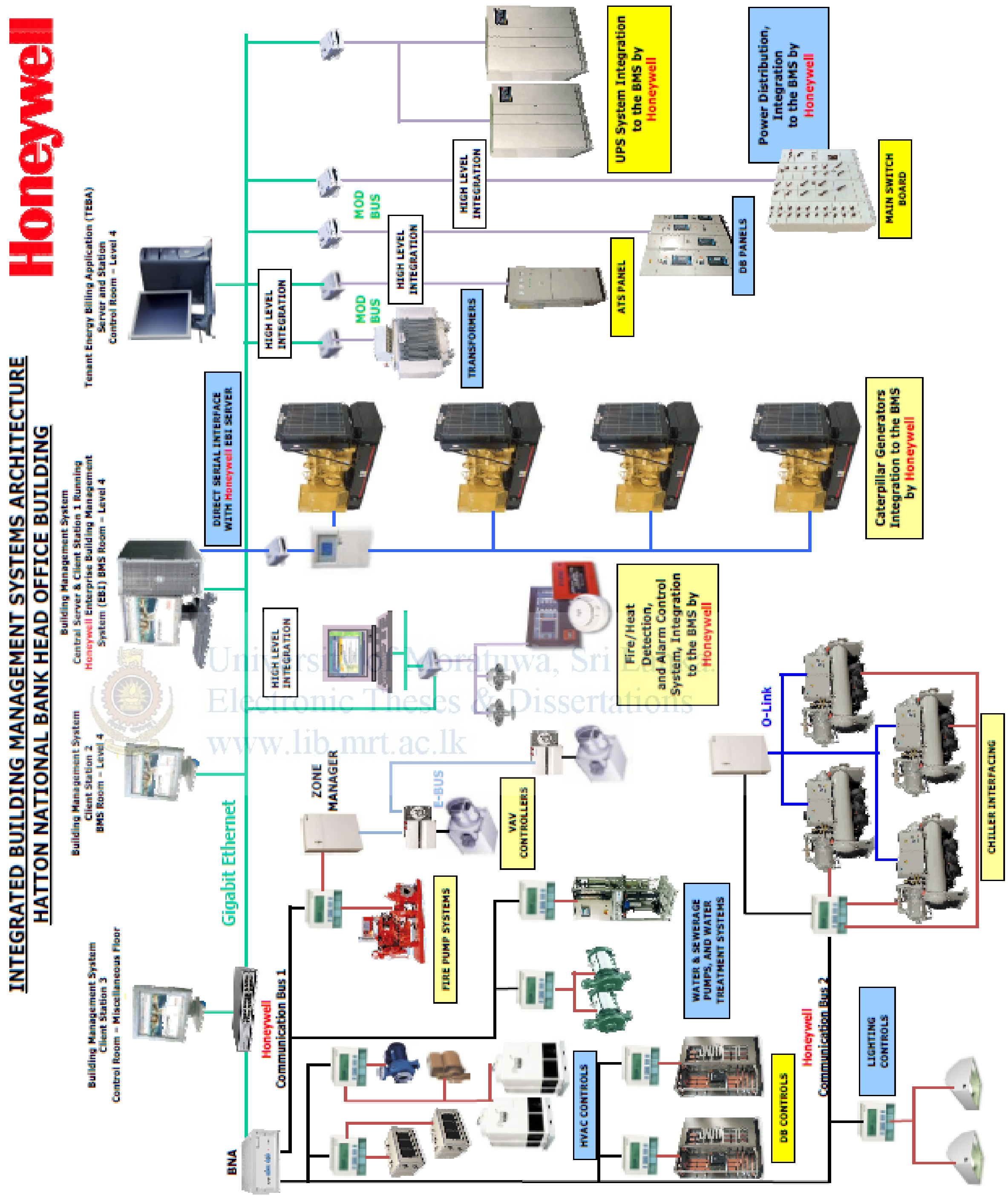


Figure 2.2: BMS Architecture HNB Tower

2.10 Energy Metering Devise

2.10.1 Electrical Power Analyzers

Electrical Power Analyzers are most important devises for the TEBA Systems for gathering the data. Following applications are applied electrical power analyzers for the TEBA Systems.

To Measure Plant power consumptions in the chilled water plant including Chillers, Chilled water pumps, Condenser water pumps etc.

To measure power consumption AHU, Lighting Systems and other power consumed equipments power consumptions.

The High End multifunction power meter used in BAS & TEBA Systems including following measuring & monitoring futures with the integrated to the system via communication interfaces,

- True-RMS Measuring Parameter
- ANSI C12.20(0.2 Class) and IEC 62053-22(0.2S Class)
- Power Quality Analysis
- Over Limit Alarm
- Multi Communication Ports (Eg: Ethernet, Modbus,Plofi Bus)

2.10.2 Thermal Energy BTU Meters

Thermal energy BTU meters are used for measured thermal energy consumption through hot water or chilled water in the system. The BTU meters are consist of water flow meter & two temperature sensors for measure supply & Return water Temperature through AHU Cooling or Heating coil.

The Flow meters may be Electromagnetic type, Turbine type, Positive displacement type or vane types. The temperature sensors may be Negative thermo couple, PT 100 or PT 1000.The measurement accuracy is depending on sensor type and their applications.

Typical digital BTU meters is a fully user programmable digital flow meter capable of measuring flow rate along with totalized flow, & batching of conductive liquids. Manufactured using latest technology, the microcontroller and embedded software used in the instrument offers better accuracy and user convenience. The flow meter is supplied as two components. The sensor and transmitter The sensor converts the flow of the fluid in the pipe to an electrical signal and transmits it through a cable to the Transmitter. The second component is the transmitter, which consists of the sensor drive and a flow computer. The sensor drive provides the excitation voltage for the field coils in the sensor. The flow computer converts the velocity signal to actual flow and also totalizes the flow. Proper signal conditioning is done using special algorithms to compensate for undesired flow patterns. All the programmable values , are stored in the internal non volatile memory.

The totalized flow is also backed up in this non volatile memory during power down, and recalled during power up. This feature enables the instrument to totalize only on the last value, Front key panel can be used to reset to talizer to zero. The nonvolatile memory is capable of storing all the user settable data and retain the data even during power down. The memory is capable of storing this data for a period of 100 years. Each data value , that is being programmed is stored in allocations and also in two additional backup locations.

2.11 TEBA Data Analysis and Energy Information Systems (EIS).

Depending on the interval and collection frequency, metered data can accumulate quickly and become overwhelming unless some level of automated data processing is implemented. At the outset of any metering activity, it should be made clear that meters provide data and these data generally do not constitute information or knowledge. The reality of data analysis comes in the recognition that data needs to be processed to create information (knowledge) before any proactive actions can be taken. To be successful in their metering activities, the federal sector must recognize that meters and data alone are not the answer; success comes when the data are processed to create information and this information used for action. This chapter focuses on suggestions for productive uses for metered utility data as well as discusses some of the options for data analysis and processing.

An Energy Information System (EIS) is an integrated development combining analytical software and hardware (sensors and meters) with a communications system to collect, analyze, and report building energy/resource data. While these systems can be installed in a "turnkey" sense (i.e., all sensors, meters, and software are installed), many applications make use of existing hardware and communications and the EIS becomes strictly a software solution. The balance of this section will focus on the software data analysis aspects of the EIS solution.

The software aspect of the EIS can take the form of a very simple (in-house developed) spreadsheet-based routine for processing metered data, to a very complex (third-party purchased/licensed) software package with many sophisticated routines and statistical analysis capabilities.

As with the different offerings, there are a variety of fee arrangements available through these vendors. Some EIS organizations offer their service under a licensing agreement allowing only a certain number of users or "seats." Other EIS organizations offer unlimited users under a time-based subscription service and still others offer their product as a one-time software purchase with fee-based technical support. A list of EIS vendors can be found in the following references: CEC (2007) and LBNL (2002).

2.11.1 EIS Development/Selection Considerations.

Prior to making the decision to develop an in-house EIS versus purchasing/licensing a third-party product (or something in between), your organization needs to determine the options and expectations of the EIS in at least the following areas (CIPEC 2004):

Definition of facility objectives – need to be clear on how the EIS will be used, how it will improve resource efficiency, and its contribution to the financial payback of the overall metering system.

EIS integration with other IT systems – an important consideration prior to EIS selection/development is what existing infrastructure can be used. Prior to the EIS decision, a survey of existing facility software, hardware, communications, meters, and capabilities is recommended.

Identify key reporting outputs – How will the outputs of this system be used to fulfill the objectives of the facility and its management. How will the outputs be made available (paper copy, email reporting, web-based reporting) and what sort of summary options are available.

Data-collection needs – what are the data-collection requirements necessary to achieve the key reporting outputs. Are these available with existing metering elements.

Data analytics – what analysis, statistical and/or regression routines are needed to transform the data to into the information desired? Are the chosen analytics capable of handling the size, frequency, and complexity of anticipated data?

Management support – has a budget been developed addressing expenses such as ongoing training, periodic testing, technical assistance, and troubleshooting?

Data Storage- What is the database compatibility for the EIS? Is it compatible with the following systems?

Web-service client with Extensible Markup Language (XML) Open Database Connectivity (ODBC) compliant to interface third-party software application Structured Query Language (SQL)__Application Program Interface (API) to communicate with specific field devises such as handheld equipment Is the database and the data transfer through the Internet encrypted.

2.12 Data Output Considerations.

The final element for consideration in EIS development or selection is the output information. Prior to development or selection, facilities staff need to review the objectives and goals of this entire metering system. Once identified, these can be used to help shape the type and form of EIS output necessary to achieve these objectives. Assembled below are a variety EIS output options collected from different vendors and resources. These are grouped into the categories of graphical outputs, analytical outputs, system-specific outputs, and utility outputs. While these categories are not all-inclusive, they should provide some guidance in identifying the capabilities and outputs advantageous to you and your systems. One additional caution, as you make your decisions on vendors and levels of service/outputs, keep in mind the associated volume of data and the necessary time to process and act on the data. The recommendation is to start with a manageable set of outputs that can be useful in the expected time allocated. Then, as the system becomes more integrated, look to add features and other options. To start – keep it simple.

2.12.1 Graphical Outputs:

Consider these as the plots you and your staff interact with on a daily, weekly, and monthly basis. Make certain axes are scaled and labeled for intuitive understanding now and into the future.

Daily profile: Time-series daily load profiles are displayed with time, in intervals of an hour or less, along the horizontal axis and load along the vertical axis.

Day overlay: Overlay plots display multiple daily profiles on a single 24-hour time-series graph.

Multi-point overlay: Allows viewing of multiple time series data points on the same graph.

3-D surface chart: Three-dimensional surface charts often display the time of day, date, and variable for study.

Calendar profile: View up to an entire month of consumption profiles on a single screen as one long time series.

X-Y scatter plots: X-Y scatter plots are useful for visualizing correlations between two variables.

2.12.2 Analytical Outputs:

Consider which analyses will be most useful and incorporate those into the EIS as an automated function. The goal is to minimize the amount of exporting and re-analyses needed.

Basic statistical analysis: Perform statistical calculation, such as mean, median, standard deviation, correlation, and regression.

Benchmarking: Benchmark against building energy standards or public database such as EnergyStar.

Intra/inter-facility comparisons: Benchmark against the building's historical data or across multiple buildings in the enterprise.

Aggregation: Aggregate data among multiple data points. Integrate different energy units using energy conversions (e.g., kWh, Therm, etc., into Btu).

Data mining (data slice/drill-down): Sum-up/drill-down time series data by monthly, weekly, daily, hourly, or trended interval.

Normalization: Normalize energy usage or demand by some factors such as building area, number of occupants, outside air temperature, and cooling or heating degree-days (CDD, HDD) to make a fair comparison between buildings.

Hierarchical summary: Summarize usage and cost information by different levels. For example, starting from equipment energy cost, individual building energy cost, site energy cost, to regional energy cost.

2.12.3 System-Specific Outputs:

Look for customized analyses beyond the "graphical and analytical" outputs mentioned above. This type of analysis often takes multiple data points and use more complicated algorithms.

Power quality analysis: Monitor the voltage or current phases for conditions that could have adverse affect on electrical equipment.

Steam charts: Calculate temperature, pressure, specific volume, and enthalpy for saturated steam and water.

Forecasting: Forecast future trends by historical data and related parameters.

Validation, editing, estimation: A process performed to ensure quantities (kWh, kW, kVar, etc.) retrieved from meters are correct. The process includes validation of data within acceptable error tolerances, editing or correcting erroneous data, and estimating missing data.

Equipment fault detection and diagnostics: Diagnose equipment failure or degradation based on customized algorithm and parameters.

2.12.4 Utility Outputs:

Consider how these data can be useful in interactions with your utilities. Typically, there are tools allowing rate comparisons, bill verification, etc.

Invoice verification (bill validation): Utility bills are compared to meter readings (so called "shadow" metering) to validate accuracy of bills.

Energy cost drilldown: Using energy tariff and usage data, calculate daily or hourly energy cost breakdown, instead of the usual cost that can only be seen in monthly utility bills.

Real-time cost tracking: Calculates electricity costs every day or hour using real-time meter reading and rate tariffs.

End-use cost allocation: According to user-defined parameters and algorithms, estimates end-use energy consumption from whole building energy. Generally used for cost allocation to building tenants. A common parameter definition is energy use per square foot.

3. TEBA SYSTEM MODEL

3.1. Chiller Plant Arrangement & Pump System

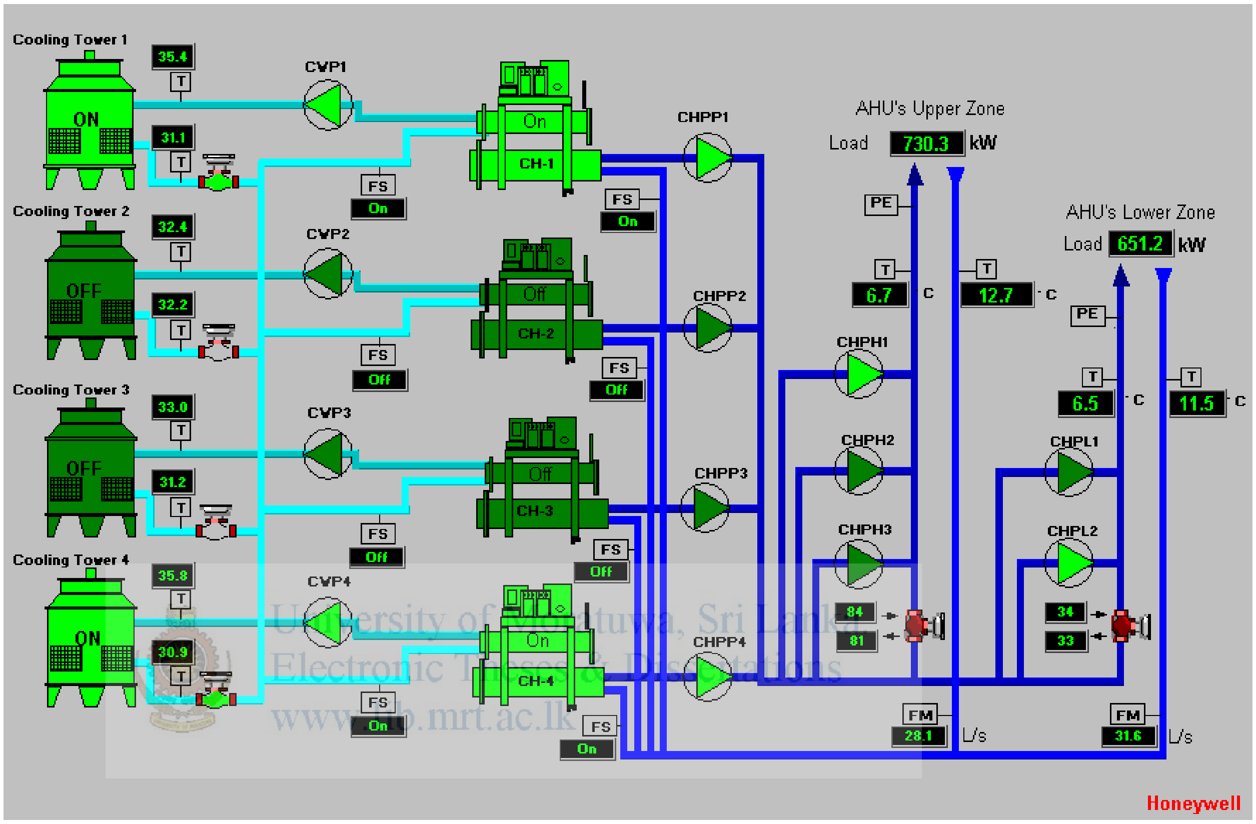


Figure 3.1: Chiller Plant Lay out Diagram

In primary/secondary systems, water flows through the chiller primary loop at a constant rate, and water flows through the secondary loop, which serves air handlers or fan coils, at a variable rate. The constant speed pumps in secondary circuit are replaced with “variable speed” pumps. The speed of the secondary pumps is determined by a controller measuring differential pressure across the supply-return mains or across the selected critical zones. The decoupled section isolates the two systems hydraulically.

Also the system uses two-way valves in the air handlers that modulate secondary loop flow rate with load requirements. During light load condition, the 2-way control valves will close (partially or fully) in response to load conditions, resulting in pressure rise in the secondary chilled water loop. A differential pressure sensor measures the pressure rise in the secondary loop and signals variable frequency drive of secondary pumps to alter the speed (flow).

Primary-secondary variable-flow systems are more energy efficient than constant-flow systems, because they allow the secondary variable-speed pump to use only as much energy as necessary to meet the system demand. Refer to the schematic below.

3.2 Data Acquisition in the Chiller Plant.

3.2.1 Chiller Electrical Consumption-

Individual Chiller Power Consumption measured using Current Transformer connected Power Transducers with following specifications.

- Quantity – 4 Numbers
- Type – Active Power Transducer
- Communication Signal- 4-20mA Signal
- Input Range- 0-5A
- Manufacturer- Adision
- Accuracy: 0.2%
- Rated of output Input frequency: 50Hz 3Hz or 60Hz 3Hz
- Input burden: 0.1 VA (ampere input)   0.2 VA (voltage input) Aux.
- Power supply: 50/ 60Hz   AC 220V 15%,
- Power effect: 0.1% RO.
- Power consumption: 4 VA, DC

Figure 3.2: Power Transducer

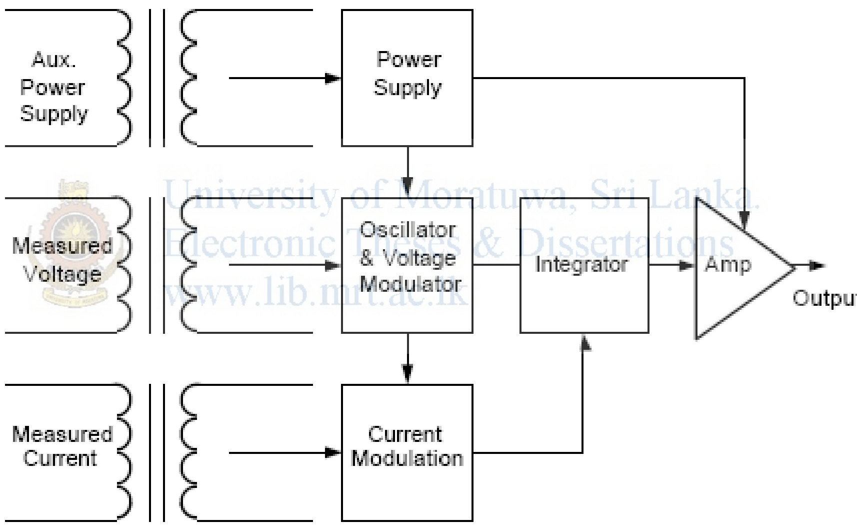


Figure 3.3: Power Transducer Functional Block Diagram

3.2.2 Chilled water, Condenser water & Cooling Tower Power Consumption

Separate pumps Set power consumption measured using Mod-Bus communication type electricity power Analyzers.

3.2.2.1 Property of the power analyzer

Applications

- Metering of distribution feeders, transformers, generators, capacitor banks and motors
- Medium and low voltage systems
- Commercial, industrial, utility
- Power quality analysis
- Data Logging

Metering Parameters

- Voltage V1, V2, V3, V ln avg, V12, V23, V31, Vl lavg
- Current I1, I2, I3, In, Iavg
- Power P1, P2, P3, Psum
- Reactive Power Q1, Q2, Q3, Qsum
- Apparent Power S1, S2, S3, Ssum
- Frequency F
- Power Factor PF1, PF2, PF3, PF
- Energy Ep_imp, Ep_exp, Ep_total, Ep_net
- Reactive Energy Eq_imp, Eq_exp, Eq_total, Eq_net
- Apparent Energy Es
- Demand Dmd_P, Dmd_Q, Dmd_S, Dmd_I1, Dmd_I2, Dmd_I3Monitoring
- Power Quality
- Voltage Harmonics 2nd to 63rd and THD
- Current Harmonics 2nd to 63rd and THD

3.2.2.2 Futures of the Power Analyzer

1. **Alarms Limits:** can be set for up to 16 indicated parameters and can be set with a specified time interval. If any input of the indicated parameters is over or under its setting limit and persists over the specified time interval, the event will be recorded with time stamps and trigger the Alarm DO output. The 16 indicated parameters can be selected from any of the 51 parameters available.

2. **I/O option module :** The E-module® technique was adopted for its flexibility and easy expansion of the I/O function of Acuvim II. A maximum of 3 modules can be used for one meter. Digital input, digital output, pulse output, relay output, analog input and analog output are provided by I/O option module.

3. **Communication :** RS485, Industry standard Modbus™ protocol Module Option: Ethernet module, Profbus-DP module Dual communication ports Display Clear and large character LCD Screen display with white back light Wide environmental temperature endurance

4. **Display Load percentage**, 4 quadrants power and load nature

5. **Data logging** The Acuvim II R model offers 2MB of onboard data logging memory to be used for historical trending. There are 3 assignable historical logs where the majority of the metering parameters can be recorded. A real time clock allows for any logged events to be accurately time stamped.

3.2.3 Chilled water flow rate (Danffos MAG5000)

Individual riser water flow rate measured using electromagnetic type water flow meters.

3.2.3.1 Design details

- Compact or remote mounting possible
- Easy “plug & play“ field changeability of transmitter
- Ex ATEX and FM/CSA versions
- High temperature sensor for applications with temperatures up to 180°C (356°F)
- Approvals for PTB, OIML R75 and OIML R117
- Meets EEC directives: PED, 97/23/EC pressure directive for EN1092-1 flanges
- Build-in length according to ISO13359
- Onsite or factory upgrade to IP68/NEMA6P of a standard sensor.

3.2.3.2. Mode of operation

The flow measuring principle is based on Faraday’s law of elec-tromagnetic induction according to which the sensor converts the flow into an electrical voltage proportional to the velocity of the flow. Integration of the complete flow meter consists of a flow sensor and an associated transmitter MAG5000, 6000 and 6000I.The flexible communication concept USM II simplifies integration and update to a variety of fieldbus systems such as HART, FOUNDATION Fieldbus H1, DeviceNet, PROFIBUS DP and PA, Modbus RTU/RS485.

3.2.3 Chilled water Riser supply and return Temperature (Honeywell TE 210)

Measured by using PT100 type temperature transducers with following specifications.
Signal conditioning is performed by industrial quality integrated circuits to provide a true linear output. The circuit is factory calibrated but zero and span trim measure provided to adjust the output if necessary. Output accuracy is not affected by long wire runs or electrical noise. The transducer can operate over a wide supply voltage range. The TE-210 is available in many different housings to cover all applications. For space temperature sensing, the transducer is available in a unique plastic enclosure that has

two separate compartments divided by a solid partition. Each compartment is ventilated individually from three sides. One chamber incorporates the electronics and the other the sensing element. In this way there is total isolation between the electronics and the sensor to assure accuracy. For air duct temperature, the sensor is encapsulated in a 1/4 inch OD aluminumor stainless steel probe. The probe protrudes from the bottom of the die cast aluminum transducer housing minimizing lead length error. The probe can be inserted directly into the duct and mounting holes are provided to rigidly support the assembly. TE-210 is also available in a bendable aluminum 3/8 inch OD extra long probe for averaging duct air temperature. The probe incorporates numerous sensors encapsulated at equal distances across the length of the probe. The complete assembly acts as a single sensor and any temperature change is averaged across the sensors. The probe can be easily bent to fit any size duct. For monitoring water temperature, the TE-210 is available in a die cast aluminum enclosure with a 1/4 inch OD, probe with a brass fitting that can be screwed directly into any thermowell providing a rigid support to the transducer. The TE-210 is also available with a remote probe to be strapped on a pipe or any other application in which high temperatures are encountered. For monitoring outside air temperature the TE-210 is also available in a weather proof enclosure with a suitable sun shield to be mounted outside.

3.3 AHU Details in the Selected System.

Selected Chilled water system including with 39 numbers of AHU's with following capacities.

No	Level	AHU No	Area m2	Electrical Moter (kW)	Cooling Capacity (W)
1	Level Mez	AHU-1	280	5.50	52030
2	Level-01	AHU-2	1147	15.00	148940
3	Level-02	AHU-3	848	11.00	115280

4	Level-03	AHU-4	1081	11.00	121220
5	Level-04	AHU-5	459	7.50	79750
6	Level-05	AHU-6	514	5.50	64460
7	Level-06	AHU-7	514	5.50	64460
8	Level-07	AHU-8	514	5.50	64460
9	Level-08	AHU-9	514	5.50	64460
10	Level-09	AHU-10	349	3.00	23650
11	Level-09	AHU-11	349	4.00	39160
12	Level-10	AHU-12	483	4.00	44880
13	Level-10	AHU-13	483	7.50	106480
14	Level-10	AHU-14	766	16.50	298650
15	Level-11	AHU-15	774	11.00	110550
16	Level-11	AHU-16	774	7.50	71830
17	Level-12	AHU-17	782	11.00	110550
18	Level-12	AHU-18	782	7.50	71830
19	Level-13	AHU-19	782	11.00	110550
20	Level-13	AHU-20	782	7.50	71830
21	Level-14	AHU-21	1588	18.50	210100
22	Level-15	AHU-23	788	11.00	110550
23	Level-15	AHU-24	788	7.50	70950
24	Level-16	AHU-25	781	11.00	110550
25	Level-16	AHU-26	781	7.50	66770
26	Level-17	AHU-27	775	11.00	110550
27	Level-17	AHU-28	775	7.50	65230
28	Level-18	AHU-29	769	11.00	110550
29	Level-18	AHU-30	769	7.50	64460
30	Level-19	AHU-31	763	11.00	110550
31	Level-19	AHU-32	763	7.50	63580

32	Level-20	AHU-33	757	15.00	120890
33	Level-20	AHU-34	757	7.50	66440
34	Level-21	AHU-35	514	4.00	35420
35	Level-21	AHU-36	514	5.50	43509
36	Level-21	AHU-37	514	7.50	65077
37	Level-22	AHU-22	374	5.50	49500
38	Level-22	AHU-38	374	5.50	36121
39	Level-22	AHU-39	374	11.00	248710

Table 3.1: Air Handling Unit Data

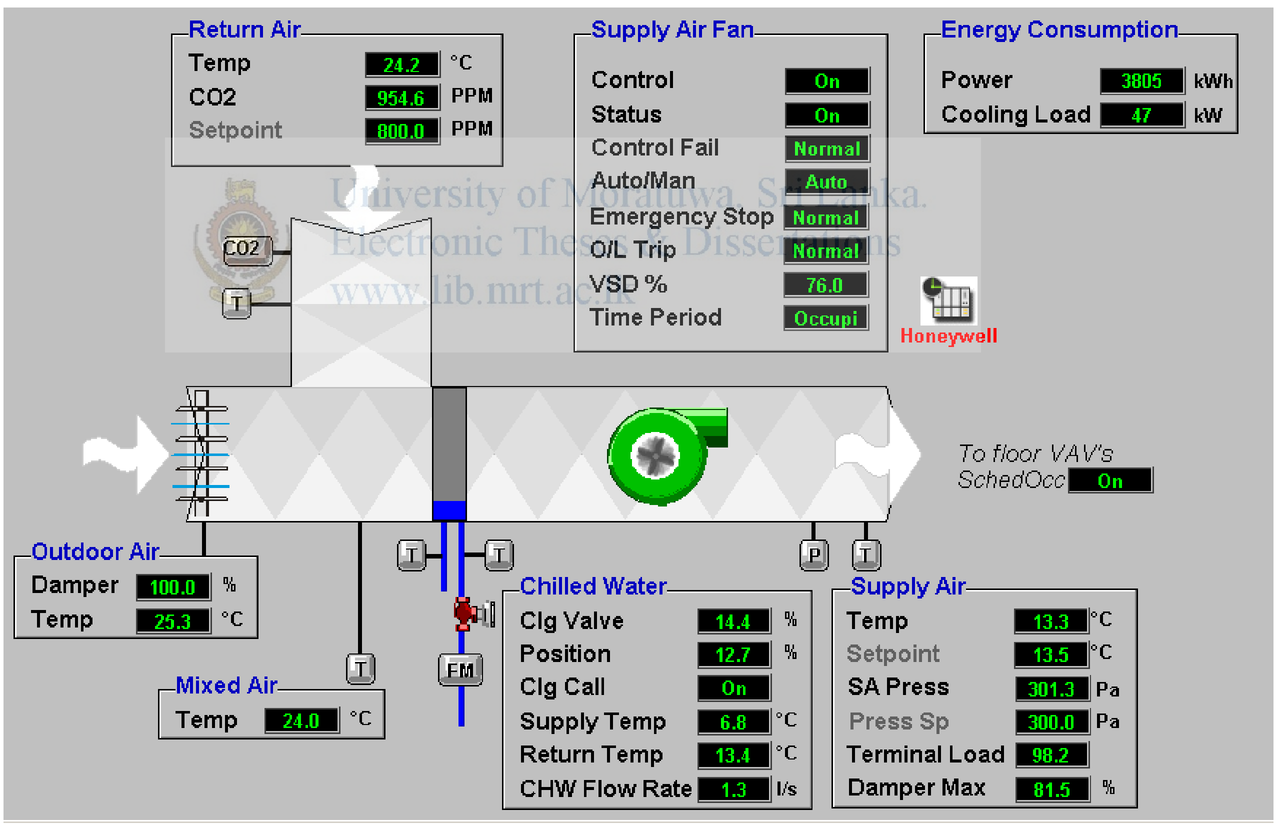


Figure 3.4: AHU Equipment Layout

3.4 Data Acquisition in the Air Handling Units (AHU).

3.4.1 Chilled water Flow Rate

Measured using Turbine type water flow meter with following specifications.

- Power Requirements: 5 to 24 V DC Output
- Signal: Open collector, sinking, proportional to flow velocity Output
- Current: 10 mA max.
- Flow rate range: 0.3 to 20 fps (0.1 to 6 m/sec)
- Pipe size range: 1.5 to 24 in.
- Fitting thread size: 1.5 in. NPT
- Linearity: ± 1% of full range
- Repeatability: ± 0.5% of full range
- Body diameter: 0.94 in. (2.4 cm)
- Standard cable length: 25 ft (7.6 m)(1000 ft [305 m] max. recommended)
- Cable type: Twisted pair with foil shield(Belden 8451)
- Pressure / Temperature rating: 250 psig(17 bar) max. @ 212°F (100°C)
- Sensor MaterialsBody: 316 SS

Supply water Temperature - Measured using Honeywell TE 210 PT100 type temperature transducers.

Return water Temperature - Measured using Honeywell TE 210 PT100 type temperature transducers.

AHU Fan motor electricity consumption – Measured by using CT connected power transducers.

3.5 Data Acquisition SCADA Software

The Selected BMS System with Honeywell Enterprises Building Integrator Software for data Acquisition. The Honeywell Enterprise Buildings Integrator uses client-server architecture on Windows NT to provide cost-effective scalability to any enterprise without the need for proprietary hardware. Operator stations can be connected using a variety of standard TCP/IP network topologies such as LAN and WAN as well as serial and dial-up access. Databases and applications can be integrated to provide various local, network and internet clients access to monitoring, control, past performance and management reporting. Honeywell EBI provides tight business level integration so that human resources information flows directly into the Honeywell Security Manager application. To help you achieve optimal maintenance strategies, maintenance management packages receive breakdown information and performance monitoring information from the Honeywell Building Manager application. Standard SQL access to building performance data allows boardrooms to truly see operational impact on their bottom line by linking this data into financial systems.

4. TEBA ENERGY CALCULATION PROCEDURE

Tenant billing amount is calculated based on the energy utilized by a tenant and energy rate. Energy utilized by the tenant includes cooling load (refrigerant ton) at the AHU and electrical energy absorbed by equipment.

4.1.1Cooling Load Calculation

Tenant cooling load energy is calculated based on,

- Total refrigererent tons generated at the AC plant (Q_T)
- Refrigerant tons used by the tenant AHU (Q_t)
- Total Electrical Energy Input to the Central AC Plant (E), which includes
  Total electrical energy input to the central AC plant except cooling towers (E_1)
    - Chillers
    - Primary Chilled water pumps
    - Secondary Chilled water pumps
- Total electrical energy input to the cooling towers (E_2)
    - Cooling Towers
    - Water treatment System
- Electrical energy input to the tenant Air handling unit equipments (e_t)

The each valve determination procedure as bellow,

4.1.2 Total cooling load at the AC plant $(\boldsymbol{Q_T})$

Refrigerant Ton value at the AC plant can be determine by following formula,

$$Q = w * c * (T_i - T_o) \qquad (4, 1)$$

Since there are two zones in the building the flow and temperature are measured at two locations.

The total cooling load can be calculated by following formulas.

Cooling load low Zone

$$Q_l = w_l * c * (t_{ol} - t_{il}) \qquad (4, 2)$$

Cooling load high Zone

$$Q_h = w_h * c * (t_{oh} - t_{ih}) \qquad (4, 3)$$

Total Cooling Load

$$Q_T = Q_l + Q_h \qquad (4, 4)$$

TEBA shall communicate with EBI server and retrieve the cooling load data (Flow rate, Temperature Valves) for all the configured points at a fixed time interval of every 6 minutes. This update prases shall be round the clock and any way make sure that any data that is not update in the previous scan cycle is updated in the next scan cycle. For this poupous, TEBA shall get the historical point data from EBI server. All the cooling load data shall be stored with correct data time stamp.

4.1.3 Total Cooling Load (Q_t) Used by Tenant AHU

Total cooling load used by the tenant AHU (Q_t) can be calculated using two temperature Sensor in supply & Return Chilled water line and the flow meter .Cooling load value at the AHU can be determined by the following formulas.

$$Q_t = W_t * C * (T_{ot} - T_{it}) \qquad (4, 5)$$

Where,

Q Heat flow rate in *kW*

W Chilled water mass flow rate in *kg/sec*

T_i Incoming Water temperature *˚C*

T_o Outgoing Water temperature *˚C*

c Specific Heat in *kJ/kgK*

4.2.1 Total Electrical Energy (E_r) used by Cooling Plant.

Electrical used by the AC plant is the summation of electrical energy used by central AC plant except cooling towers and electrical energy used by cooling towers.

$$E_r = E_1 + E_2 \qquad (4, 6)$$

Where,

E_r(kWh) Total Electrical energy input to the central AC Plant (Chillers, CHWPs, CWPs and Cooling Towers)

E_1(kWh) Total Electrical energy input to the central AC Plant except Cooling Towers

E_2(kWh) Total Electrical energy input to the Cooling Towers

All cooling plant electrical energy values shall be stored in a separate table. Total energy value is the summuation of all electrical point values at a given time instant.

4.2.2 Electrical Energy (e_t) used by Tenant AHU Equipments

Electrical used by the tenant AHU is the summation of electrical energy used by AHU fan motor, outdoor fan motor.

$$e_t = e_1 + e_2 \qquad (4, 7)$$

Where,

e_t Total electricity energy input to Tenant air handling unit in kWh

e_1 Electricity energy input to Tenant air handling unit fan motor in kWh

e_2 Total electricity energy input to Outdoor Air Fan Motor in kWh

$$Q_h = W_h * C * (t_{oh} - t_{ih}) \qquad (4, 8)$$

4.3 Tenant Energy Bill

Tenant Energy is calculated based on the amount of refrigerant and electricity being used by tenant's AHU for short duration of time as declared in the application.

Since the parameters are varying ever time this kind of energy calculation is valid for small time interval only.

4.4.1 Tenant Energy Bill (for time *t*)

$$\boldsymbol{TEB_t = Ammount\ for\ Refrigiration\ Ton + Amount\ for\ Electricity\ (for\ AHU\ equipmant)}$$

$$TEB_t = \{((Q_t * E_r)/Q_r) + e_t\}*MF*R \quad (4, 9)$$

Where,

MF Maintenance Factor

R Rate of change for Electricity *Rs/kWh.*

E_r Total electrical energy input to the AC Plant in *kWh.*

e_r Total electrical energy input to the AC Plant in *kWh.*

Q_r Total Cooling load for AC Plant (Zone 1 & 2) only for time t in *kW.*

Q_t Total Cooling load for tenant only for time t in *kW.*

$\boldsymbol{TEB_t}$ **Tenant Energy Bill for time $\boldsymbol{t}$.**

Since the above said calculation is only for a period of time, the monthly tenant energy bill is the summation of such values for a month period.

$$\mathrm{TEB_{in\ Rs}} = \mathrm{TEB_{t1}} + \mathrm{TEB_{t2}} + \cdots \ldots \ldots \ldots + \mathrm{TEB_{tn}} \quad (4, 10)$$

4.4 Disadvantage of the System

Following disadvantages are highlighted above calculations system,

1. Real time energy balancing

   In above scenario the cooling Energy balancing is using the real time. That mean the energy generation is marched with AHU energy consumption in same time. The calculation method is not correction for the plant generated excess cooling Energy.

Cooling Energy Generation in the plant = Summation of Energy consumption of AHU's

2. There are no Correction methods of Cooling Energy Distribution loss in the system. Normally chilled water lines are insulated in the chilled water piping distribution System. But it is not indicate the distribution loss is in Zero condition. It also loss same amount of cooling energy from the system.

5. ANALYZING OF THE COLLECTED DATA

In this chapter the results of the collected data analysis are presented the system behavior using one month hourly basis historical data for 2009 August Building Automation System (BAS) stored following data.

- Chiller Plant Hourly average cooling energy production.
- Individual Air Handling Unit cooling energy consumption data.

Considering the month period gathered System generated and AHU Consumed Energy data can be indicate following two major type of system behaviors.

1. Week day (Working day)data variation – Monday to Friday without holiday
2. Weekend (Saturday) data variations – Saturday and Sunday

	Time	Average Plant Generated Cooling Energy /(kWh)	Average AHU Consumed Total Energy/(kWh)
1	1:00:00 AM	589.91	196.06
2	2:00:00 AM	760.54	315.64
3	3:00:00 AM	2,604.12	1,196.31
4	4:00:00 AM	1,526.87	629.07
5	5:00:00 AM	1,731.36	936.97
6	6:00:00 AM	8,221.94	5,496.97
7	7:00:00 AM	14,468.39	13,403.11
8	8:00:00 AM	14,815.28	13,935.71
9	9:00:00 AM	15,445.69	14,348.90
10	10:00:00 AM	16,133.34	15,402.23
11	11:00:00 AM	17,039.36	17,348.19
12	12:00:00 PM	16,740.27	16,389.26

13	1:00:00 PM	16,656.69	16,569.40
14	2:00:00 PM	16,431.45	16,387.57
15	3:00:00 PM	15,828.49	15,847.27
16	4:00:00 PM	15,278.33	15,371.93
17	5:00:00 PM	12,324.40	12,008.05
18	6:00:00 PM	6,876.63	6,026.46
19	7:00:00 PM	6,202.53	5,783.17
20	8:00:00 PM	5,554.27	5,019.83
21	9:00:00 PM	4,662.93	4,096.86
22	10:00:00 PM	1,693.57	1,165.90
23	11:00:00 PM	754.30	250.05

Table 5.1: One month average Hourly Energy data for 2009 Aug (Working day)

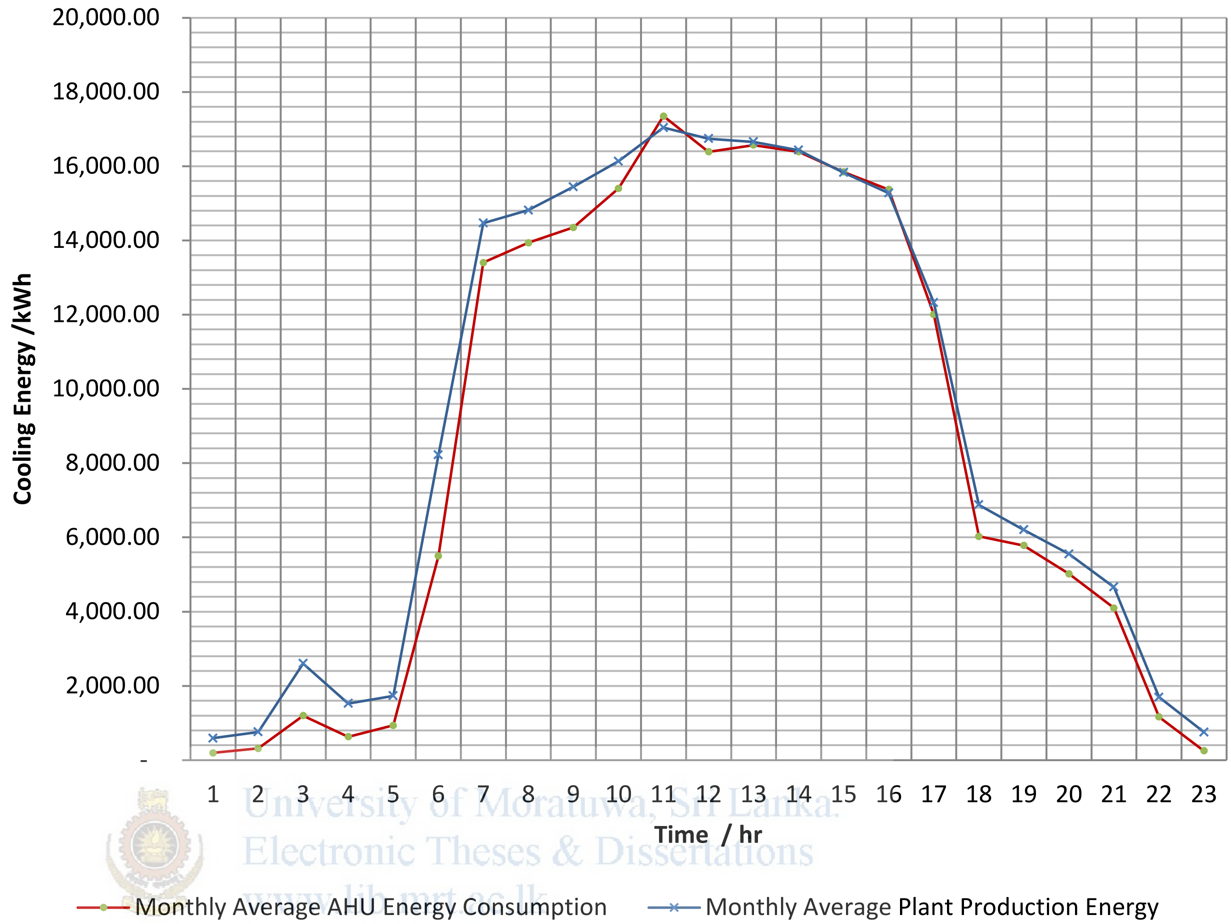


Figure 5.1: Weekday Hourly Average Energy Profile 2009 Aug

	Time	Average Plant Generated Cooling Energy /(kWh)	Average AHU Consumed Total Energy/(kWh)
1	1:00:00 AM	1,170.21	285.51
2	2:00:00 AM	1,273.71	595.91
3	3:00:00 AM	1,398.94	795.18
4	4:00:00 AM	761.71	269.95
5	5:00:00 AM	2,373.10	949.08
6	6:00:00 AM	1,581.51	563.65
7	7:00:00 AM	412.06	96.99

8	8:00:00 AM	1,904.91	722.75
9	9:00:00 AM	4,129.62	2,106.04
10	10:00:00 AM	4,276.03	2,885.70
11	11:00:00 AM	3,966.60	3,021.43
12	12:00:00 PM	3,350.86	2,492.07
13	1:00:00 PM	2,788.84	2,037.68
14	2:00:00 PM	2,110.52	1,459.79
15	3:00:00 PM	3,122.14	1,815.40
16	4:00:00 PM	2,794.33	1,640.67
17	5:00:00 PM	1,378.47	580.18
18	6:00:00 PM	886.14	278.45
19	7:00:00 PM	1,215.50	418.76
20	8:00:00 PM	3,132.97	1,589.42
21	9:00:00 PM	1,573.84	880.76
22	10:00:00 PM	1,166.63	367.60
23	11:00:00 PM	1,407.63	467.08

Table 5.2: Weekend Hourly Average Energy Profile 2009 Aug

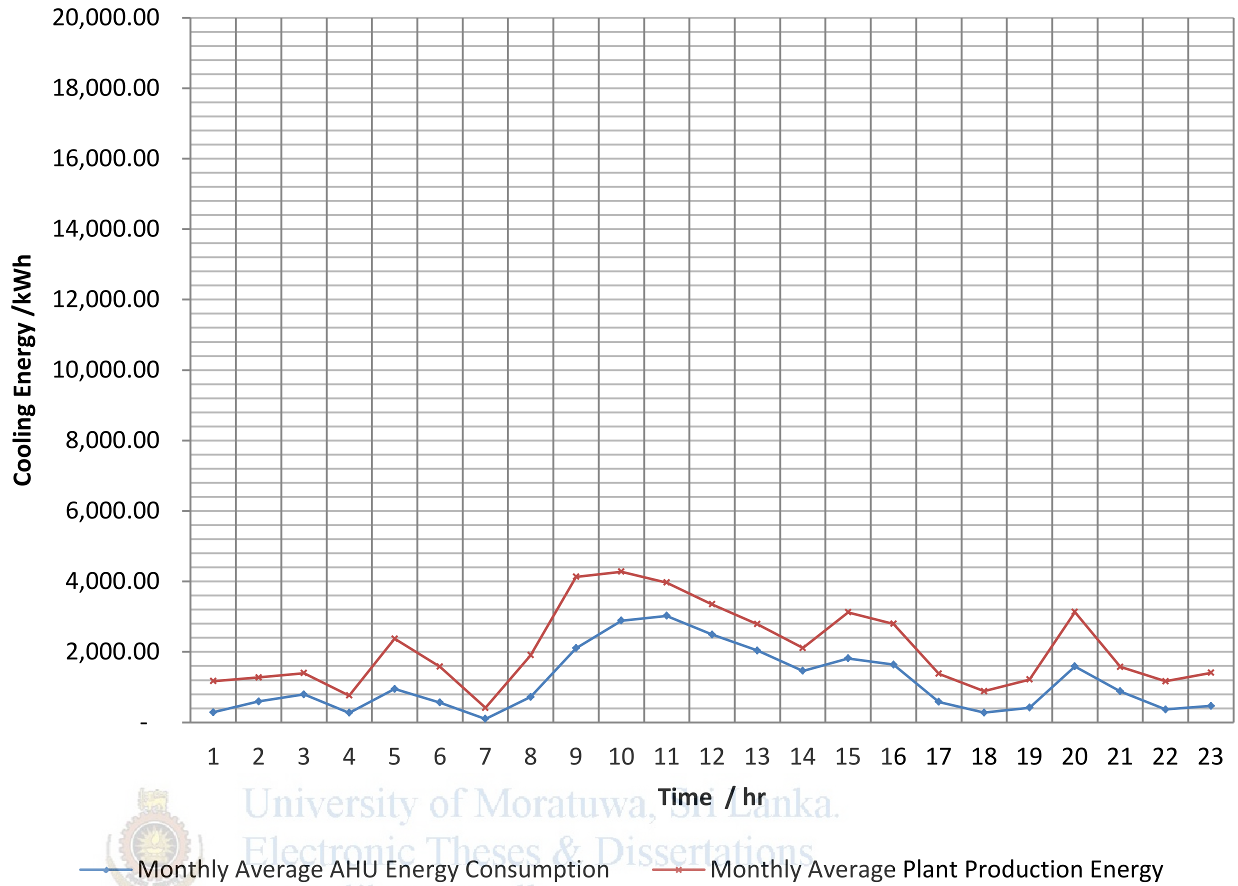


Figure 5.2: Weekend Hourly Average Energy Profile 2009 Aug

Considering the above two hourly Average energy variation per a day there is an energy difference between plant generation cooling energy & AHU consumed cooling energy data. The daily energy difference calculated by Summation of hourly based Chiller Generated Energy & Summation of total AHU Consumed Cooling Energy. The Cooling Energy difference is varying in time of the operation in the system.

Using collected Energy data calculated daily Cooling energy difference for One month period as bellow Table 5.3,

Day	Date	Plant Energy/(kWh)	AHU Consumed Energy/(kWh)	Energy Difference/(kWh)	Percentage of Energy Difference (%)
Mon	10	273021.27	251061.67	21959.60	8.04
Tue	11	244120.61	242271.75	1848.86	0.76
Wen	12	250106.73	240862.13	9244.60	3.70
Thu	13	231468.12	230645.48	822.64	0.36
Fri	14	221648.46	211975.14	9673.32	4.36
Sat	15	65015.57	39195.05	25820.52	39.71
Sun	16	47322.74	21558.11	25764.63	54.44
Mon	17	238066.86	215626.48	22440.38	9.43

Table 5.3: Weekly Energy data from Monday to Sunday

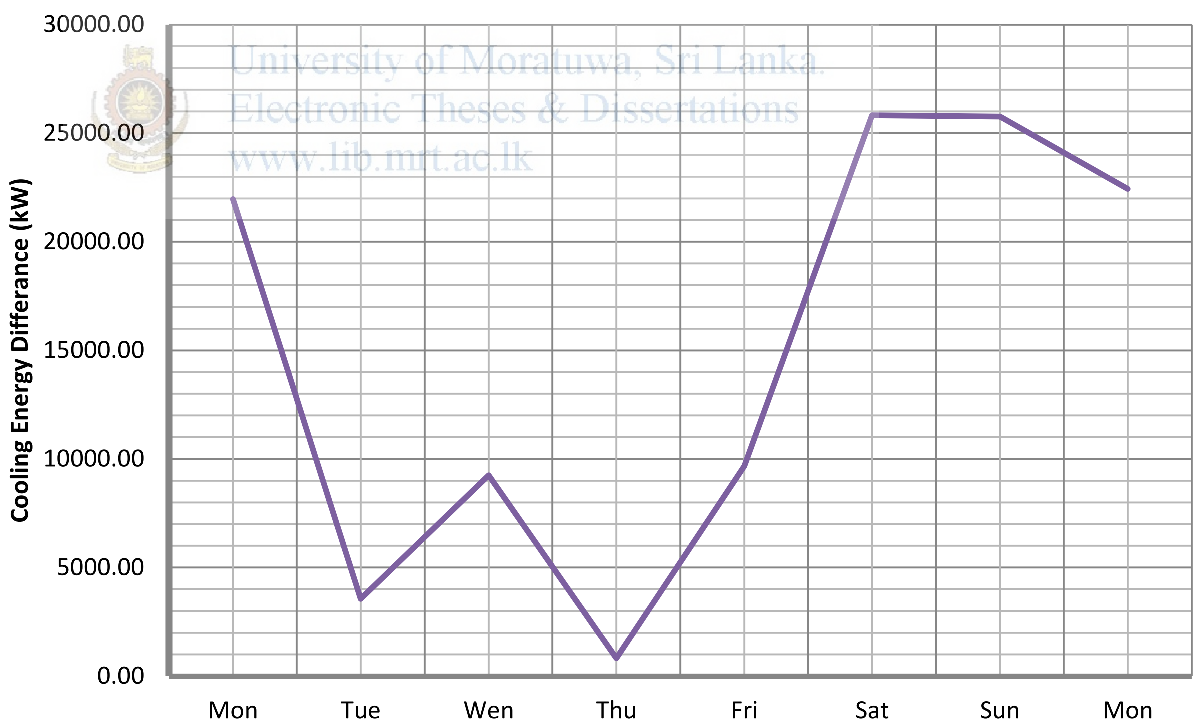


Figure 5.3: Weekly Cooling Energy Difference

Considering the above plot the energy loss indicate identical variation between week (working day) energy loss & Weekend non working day energy loss. To identify the energy loss variation of working day can be used following analysis of hourly energy loss profile.

	Time /(hr)	Average Cooling Energy Difference (kWh)
1	1.00	393.85
2	2.00	444.89
3	3.00	1,407.81
4	4.00	897.80
5	5.00	794.39
6	6.00	2,724.97
7	7.00	1,065.28
8	8.00	879.57
9	9.00	1,096.79
10	10.00	731.11
11	11.00	(308.83)
12	12.00	351.01
13	13.00	87.29
14	14.00	43.88
15	15.00	(18.77)
16	16.00	(93.60)
17	17.00	316.35
18	18.00	850.17
19	19.00	419.36
20	20.00	534.44

21	21.00	566.08
22	22.00	527.67
23	23.00	504.25

Table 5.4: Hourly Energy data for Working Day

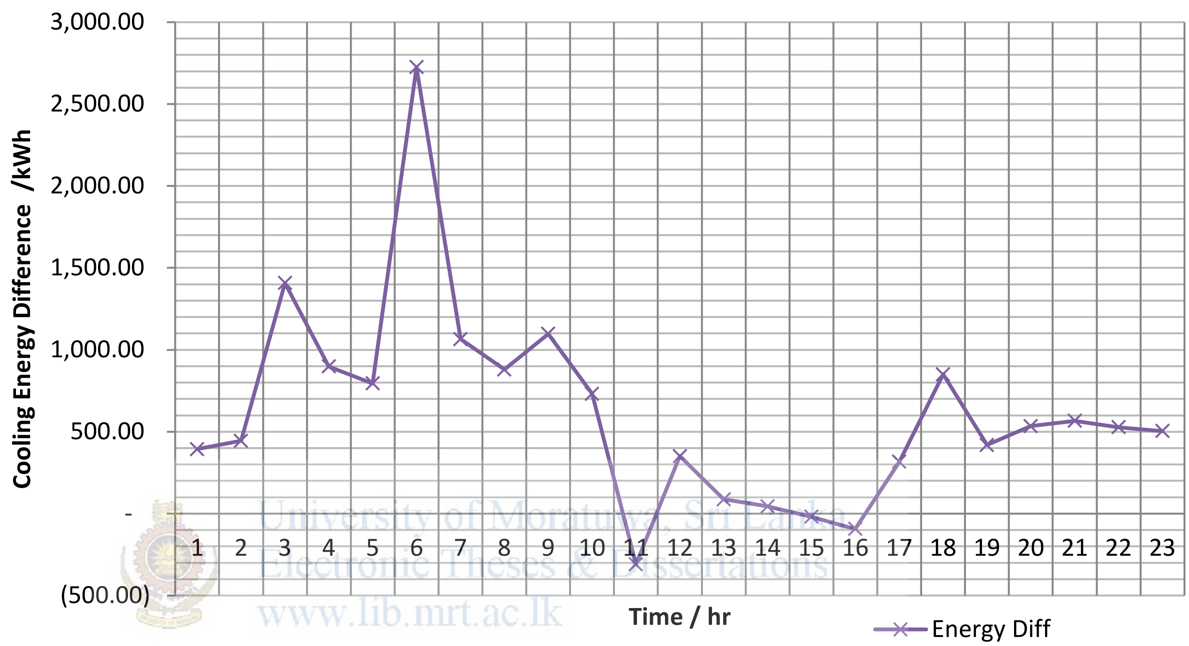


Figure 5.4: Working Day Hourly Cooling Energy Difference Profile

Considering the above data variation from Figure 5.3 & 5.4 can be identified following two difference main scenarios for daily cooling energy profile for the system.

Scenario 01

Hourly Plant Generation Energy > Summation of AHU consumed Energy

Scenario 02

Hourly Plant Generation Energy < Summation of AHU consumed Energy

Scenario 01

Plant Energy generation is higher than the Summation total AHU's Energy Consumptions. Those phenomena indicate the Distribution Energy loss and the Cooling energy stored in the system.

Scenario 02

Plant energy Generation is less than the Summation of total AHU's Energy Consumption. Those phenomena indicate Distribution Energy loss and consumed stored energy from the system.

Considering above two scenarios following two types of the cooling energy corrections to be required with the new billing strategies.

1. Correction factors for Cooling Energy distribution loss through pipe.
2. Correction factors for hourly stored energy components in the system.

6. STRATEGY Of NEW ENERGY BILLING SYSTEM

In the Chapter 05 explained collected data analysis and requirement of the new strategy for Chilled water cooling energy billing system. This chapter will introduced new energy billing concept based on Energy balancing equation.

6.1 Energy Conservation of Chilled Water Plant

Energy balancing equation can be applied as follow for the chilled water plant and distribution of the system.

$$Q_p + Q_b = \sum_{k=0}^{n} Q_i + Q_{loss} + Q_S \qquad (6, 1)$$

Q_p – Chiller generated Cooling Energy

Q_i – ith AHU Consumed Cooling Energy

Q_{loss} – Cooling Enegy loss from the system

Q_S – Stored Cooling Energy in the System

Q_b – Balanced Cooling Energy in the System

Considering Chiller plant Start and Stopping time Energy Balancing Equation for one chiller operation cycle.

For the time interval 5.00. a:m to 10 P:m and 39 Numbers of Air Handling Units

1^{st} Hour

$$Q_{p\,1} = \sum_{i=1}^{39} Q_i + Q_{loss} + Q_{S1} \qquad (6, 2)$$

2^{nd} Hour

$$Q_{p\,2} + Q_{S1} = \sum_{i=1}^{39} Q_i + Q_{loss} + Q_{S2} \qquad (6, 3)$$

N^{th} Hour

$$Q_{p\,n} + Q_{Sn-1} = \sum_{i=1}^{39} Q_i + Q_{loss} + Q_{Sn} \qquad (6, 4)$$

6.2 Estimation the Valve for the Q_{loss} Cooling Energy loss valve for the System

Cooling energy loss valve of the system is depending on the chilled water piping system following characteristics.

- Piping Materials
- Insulation Materials
- Length of the piping network
- Diameter of the piping
- Flow velocity
- Chilled water in out Temperature
- Outdoor Temperature
- Outdoor Air movement

Considering the above parameters are theoretical calculations are very complex and difficult in the System. Because can be follower following experimental analysis for the estimation valve factor for the cooling energy distribution loss.

1. Generated Zero Cooling Energy input conditions to the System.
   Chillers – Off Mode
   Primary Chilled Water Pumps – Off Mode
   Cooling Tower – Off Mode
   Condenser Water Pumps – Off Mode

2. Stat Secondary Chilled Water pumps and Circulate the chilled water One hour period and collect the following data
   - Header Energy circulation
   - AHU Energy Consumption
   - Plant Electrical Energy

Time	Plant Supply stored cooling Energy/(kWh)	Plant Electrical Energy/(kWh)	AHU Consumed Energy/(kWh)	Cooling Energy Diff/(kWh)
8/4/09 11:00 PM	447.1242	12	228.85	218.27
8/5/09 1:00 AM	410.7921	15	305.76	105.03
8/5/09 2:00 AM	394.3917	21	280.63	113.76
8/5/09 3:00 AM	374.0808	16	249.4	124.68
8/5/09 4:00 AM	359.6238	21	208.87	150.75

Table 6.1: Data for Zero Energy Input Condition

In this condition system no generation of cooling energy and circulated cooling energy that stored in previous hours generated energy.

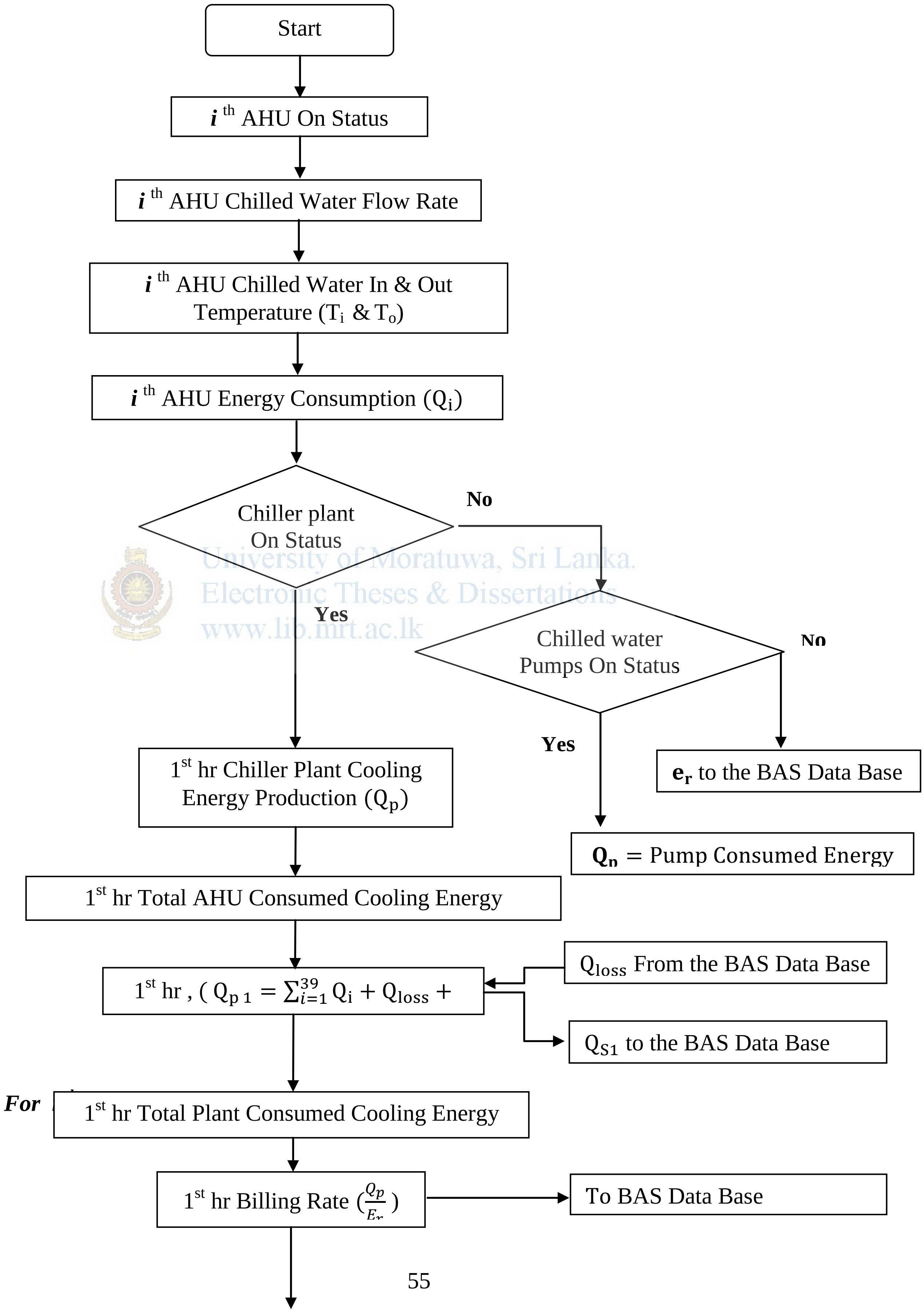
Supply Cooling Energy = AHU consumed Cooling Energy + Cooling Energy Distribution loss through the System

Chilled water pump maximum speed power consumption = 22 kW

By considering the pump maximum speed cooling energy loss as the cooling Energy distribution loss in the full load condition is constant for the system,

$$Q_{loss} = 113 \text{ kWh}$$

By substituting above valve for Equitation (6, 1) following Table 6.1 can be completed.



Start
i th AHU On Status
i th AHU Chilled Water Flow Rate
i th AHU Chilled Water In & Out Temperature (Ti & To)
i th AHU Energy Consumption (Qi)
Chiller plant On Status
No
Yes
Chilled water Pumps On Status
No
Yes
1st hr Chiller Plant Cooling Energy Production (Qp)
er to the BAS Data Base
Qn = Pump Consumed Energy
1st hr Total AHU Consumed Cooling Energy
Qloss From the BAS Data Base
QS1 to the BAS Data Base
For
1st hr Total Plant Consumed Cooling Energy
1st hr Billing Rate
To BAS Data Base

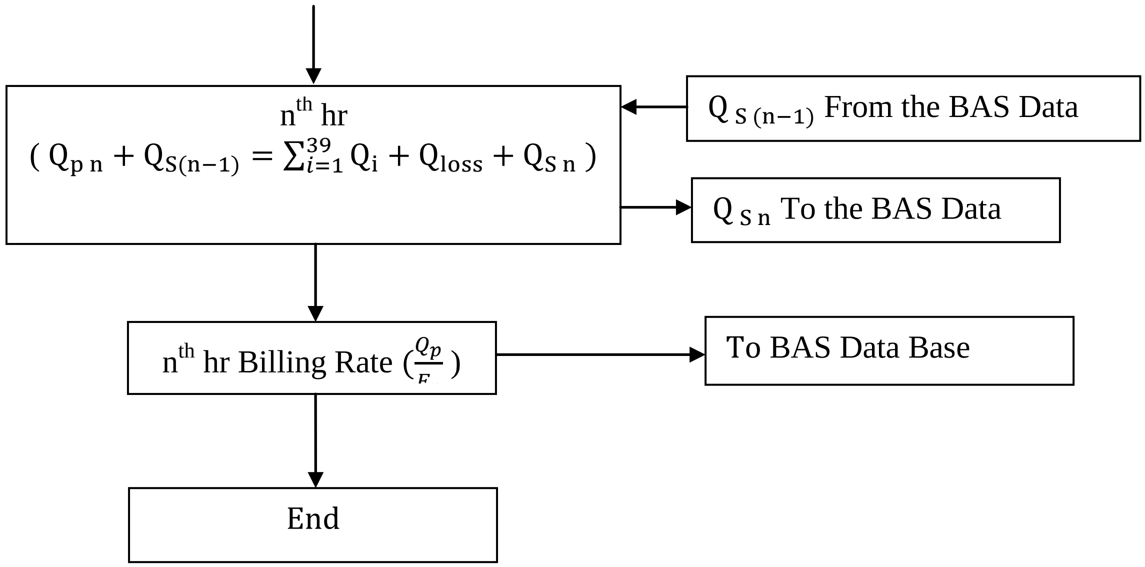


Figure 6.1: New Energy Billing Flow Chart

Time	$(Q_{p\,n} + Q_{Sn-1})$ /kW	$(Q_{p\,n})$/kW	$\sum_{i=1}^{39} Q_i$ /kW	Q_{loss}/ kW	Q_{Sn}/kW	Difference/kW
1.00 a:m	-		-	-	-	-
2.00 a:m	-		-	-	-	-
3.00 a:m	-		-	-	-	-
4.00 a:m	-		-	-	-	-
5.00 a:m	4,501.28	4,501.28	1,675.47	113.00	2,712.81	2,825.81
6.00 a:m	8,096.17	5,383.36	5,684.66	113.00	2,298.51	2,411.51
7.00 a:m	18,254.63	15,956.12	15,629.45	113.00	2,512.18	2,625.18
8.00 a:m	17,700.03	15,187.85	15,250.16	113.00	2,336.87	2,449.87
9.00 a:m	17,811.47	15,474.60	15,513.94	113.00	2,184.53	2,297.53
10.00 a:m	18,581.04	16,396.51	18,741.74	113.00	(273.70)	(160.70)
11.00 a;m	20,389.92	20,663.62	23,502.65	113.00	(3,225.73)	(3,112.73)
12.00 p:m	19,296.71	22,522.44	21,056.21	113.00	(1,872.50)	(1,759.50)
13.00 p:m	19,305.34	21,177.84	22,763.39	113.00	(3,571.05)	(3,458.05)
14.00 p;m	18,874.63	22,445.68	21,639.15	113.00	(2,877.52)	(2,764.52)
15.00 p;m	18,311.98	21,189.50	22,278.57	113.00	(4,079.59)	(3,966.59)
16.00 p:m	17,820.39	21,899.98	21,794.88	113.00	(4,087.49)	(3,974.49)
17.00 p:m	15,311.73	19,399.22	15,242.81	113.00	(44.08)	68.92
18.00 p:m	8,784.14	8,828.22	6,367.69	113.00	2,303.45	2,416.45
19.00 p:m	7,709.71	5,406.26	5,471.31	113.00	2,125.40	2,238.40
20.00 p:m	6,697.70	4,572.30	4,441.92	113.00	2,142.78	2,255.78
21.00 p:m	5,449.00	3,306.22	2,832.65	113.00	2,503.35	2,616.35
22.00 p:m	1,224.74	(1,278.61)	508.48	113.00	603.26	716.26
23.00 p:m	-	(603.26)	160.21	113.00	(273.21)	(160.21)
Total	**244,120.61**	**242,429.13**	**240,555.34**	**2,147.00**		

Table 6.2: Error Calculation Table

6.3 Result

The Table 6.3 illustrates the result comparison between before the correction of the data & after correction of the data in the Chilled water cooling energy billing system.

Date (Aug 2009)	Plant Generated Cooling Energy (kWh)	AHU Consumed Cooling Energy (kWh)	Corrected Plant Generated Cooling Energy (kWh)	Existing System Energy Error (kWh)	New System Error (kWh)	Percentage of Existing System Error (%)	Percentage of New Calculation Error (%)	Percentage of Error Correction (%)
3	285,775.06	265,602.82	276,282.90	20,172.24	10,680.08	7.06	3.87	47.06
4	259,235.77	240,687.72	250,620.35	18,548.05	9,932.63	7.15	3.96	46.45
5	107,527.29	98,090.30	103,745.01	9,436.99	5,654.71	8.78	5.45	40.08
6	253,021.43	238,652.40	248,523.97	14,369.03	9,871.57	5.68	3.97	31.30
7	246,909.89	230,109.87	239,725.17	16,800.02	9,615.30	6.80	4.01	42.77
10	262,709.11	243,021.27	253,023.91	19,687.84	10,002.64	7.49	3.95	49.19
11	207,671.26	192,356.00	200,838.68	15,315.26	8,482.68	7.37	4.22	44.61
12	228,706.40	212,902.21	222,001.28	15,804.19	9,099.07	6.91	4.10	42.43
13	231,468.12	217,484.81	226,721.35	13,983.31	9,236.54	6.04	4.07	33.95
14	221,648.46	206,584.36	215,493.89	15,064.10	8,909.53	6.80	4.13	40.86
17	238,066.86	221,309.91	230,661.21	16,756.95	9,351.30	7.04	4.05	44.19
18	234,738.53	222,121.50	231,497.15	12,617.03	9,375.65	5.37	4.05	25.69
19	224,771.45	206,988.22	215,909.87	17,783.23	8,921.65	7.91	4.13	49.83
20	229,115.57	214,338.28	223,480.43	14,777.29	9,142.15	6.45	4.09	38.13
21	201,546.86	186,419.77	194,724.36	15,127.09	8,304.59	7.51	4.26	45.10
24	239,587.72	220,645.25	229,976.61	18,942.47	9,331.36	7.91	4.06	50.74
25	218,769.75	200,066.71	208,780.71	18,703.04	8,714.00	8.55	4.17	53.41

26	210,455.01	191,666.30	200,128.29	18,788.71	8,461.99	8.93	4.23	54.96
27	215,473.80	199,195.65	207,883.52	16,278.15	8,687.87	7.55	4.18	46.63
28	206,300.10	188,925.17	197,304.93	17,374.93	8,379.76	8.42	4.25	51.77

Table 6.3: Result

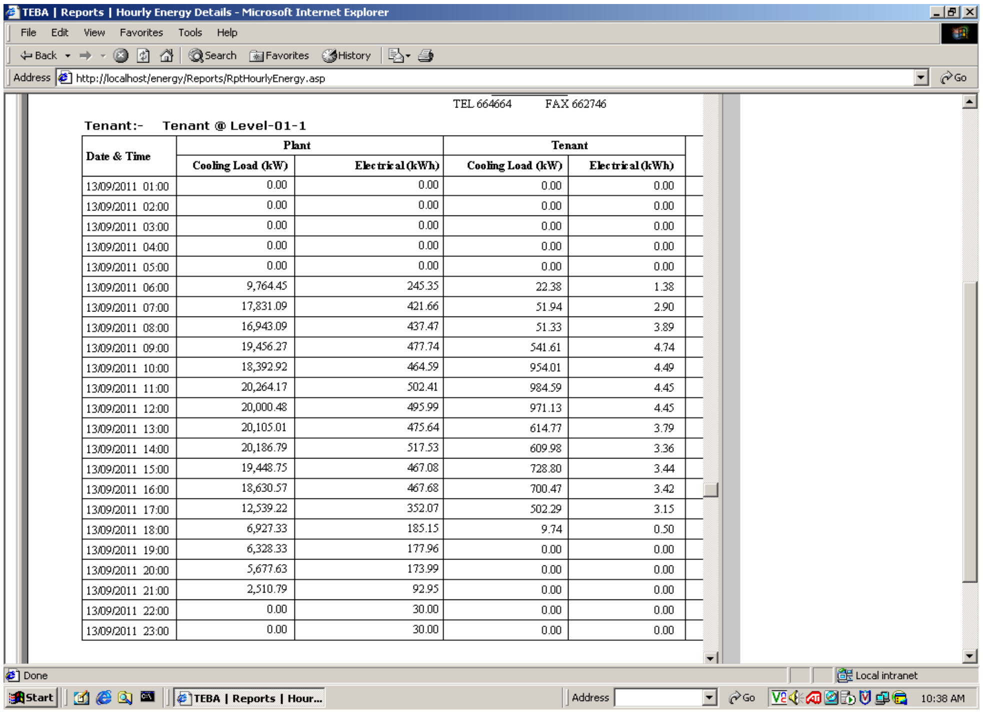
6.4 Implementation

Using the flow chart illustrated in Figure 6.1 developed new software module for calculate new energy billing corrections through the Building Management System. The new software testing in existing data from server is a difficult task and a high risk operation. There for using parallel computer running with TEBA server generated new corrected data. New software development is based on dotnet & Microsoft Excel software.

By considering of the data transfer from 13th Sept 2011 to 16th Sept 2011 following data comparison windows are obtained.

The Figure 6.2 is indicated the existing system generated report for the week day daily (13th Sept 2011) Energy production details. The Figure 6.3 is indicating the newly developed software module generated Hourly energy report in the same day with the billing strategy followed in Figure 6.1. The Figure 6.4 & Figure 6.5 are illustrate the data comparison between existing System and new System for 14th of sep 2011.

The Figure 6.8 is the Daily summarized Data Table from The Existing System Plant Generated Cooling Energy data, Summation of Total AHU Consumed Energy Data &Indicated Daily Energy Difference .

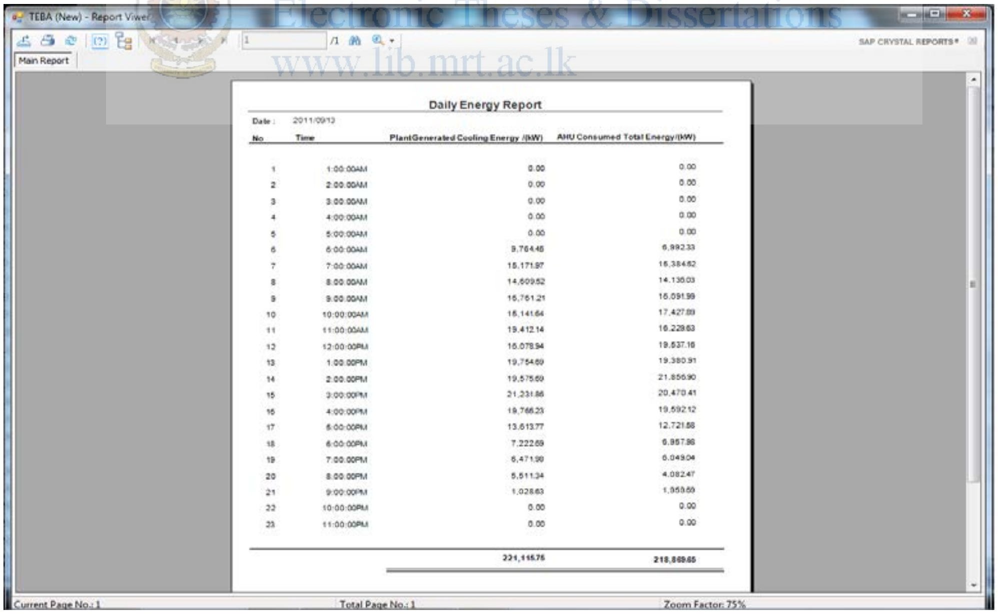


TEL 664664 FAX 662746

Tenant:- Tenant @ Level-01-1

Date & Time	Plant		Tenant	
	Cooling Load (kW)	Electrical (kWh)	Cooling Load (kW)	Electrical (kWh)
13/09/2011 01:00	0.00	0.00	0.00	0.00
13/09/2011 02:00	0.00	0.00	0.00	0.00
13/09/2011 03:00	0.00	0.00	0.00	0.00
13/09/2011 04:00	0.00	0.00	0.00	0.00
13/09/2011 05:00	0.00	0.00	0.00	0.00
13/09/2011 06:00	9,764.45	245.35	22.38	1.38
13/09/2011 07:00	17,831.09	421.66	51.94	2.90
13/09/2011 08:00	16,943.09	437.47	51.33	3.89
13/09/2011 09:00	19,456.27	477.74	541.61	4.74
13/09/2011 10:00	18,392.92	464.59	954.01	4.49
13/09/2011 11:00	20,264.17	502.41	984.59	4.45
13/09/2011 12:00	20,000.48	495.99	971.13	4.45
13/09/2011 13:00	20,105.01	475.64	614.77	3.79
13/09/2011 14:00	20,186.79	517.53	609.98	3.36
13/09/2011 15:00	19,448.75	467.08	728.80	3.44
13/09/2011 16:00	18,630.57	467.68	700.47	3.42
13/09/2011 17:00	12,539.22	352.07	502.29	3.15
13/09/2011 18:00	6,927.33	185.15	9.74	0.50
13/09/2011 19:00	6,328.33	177.96	0.00	0.00
13/09/2011 20:00	5,677.63	173.99	0.00	0.00
13/09/2011 21:00	2,510.79	92.95	0.00	0.00
13/09/2011 22:00	0.00	30.00	0.00	0.00
13/09/2011 23:00	0.00	30.00	0.00	0.00

Figure 6.2: Existing System Hourly Energy Data for Weekday



Daily Energy Report

Date : 2011/09/13

No	Time	PlantGenerated Cooling Energy /(kW)	AHU Consumed Total Energy/(kW)
1	1:00:00AM	0.00	0.00
2	2:00:00AM	0.00	0.00
3	3:00:00AM	0.00	0.00
4	4:00:00AM	0.00	0.00
5	5:00:00AM	0.00	0.00
6	6:00:00AM	9,764.46	6,992.33
7	7:00:00AM	15,171.97	16,384.62
8	8:00:00AM	14,609.52	14,136.03
9	9:00:00AM	16,761.21	16,091.99
10	10:00:00AM	18,141.64	17,427.89
11	11:00:00AM	19,412.14	16,228.63
12	12:00:00PM	16,078.94	19,537.16
13	1:00:00PM	19,754.69	19,380.91
14	2:00:00PM	19,575.69	21,856.90
15	3:00:00PM	21,231.86	20,470.41
16	4:00:00PM	19,766.23	19,592.12
17	5:00:00PM	13,613.77	12,721.88
18	6:00:00PM	7,222.69	6,957.86
19	7:00:00PM	6,471.99	6,049.04
20	8:00:00PM	5,511.34	4,082.47
21	9:00:00PM	1,028.63	1,959.69
22	10:00:00PM	0.00	0.00
23	11:00:00PM	0.00	0.00
		221,115.75	218,869.65

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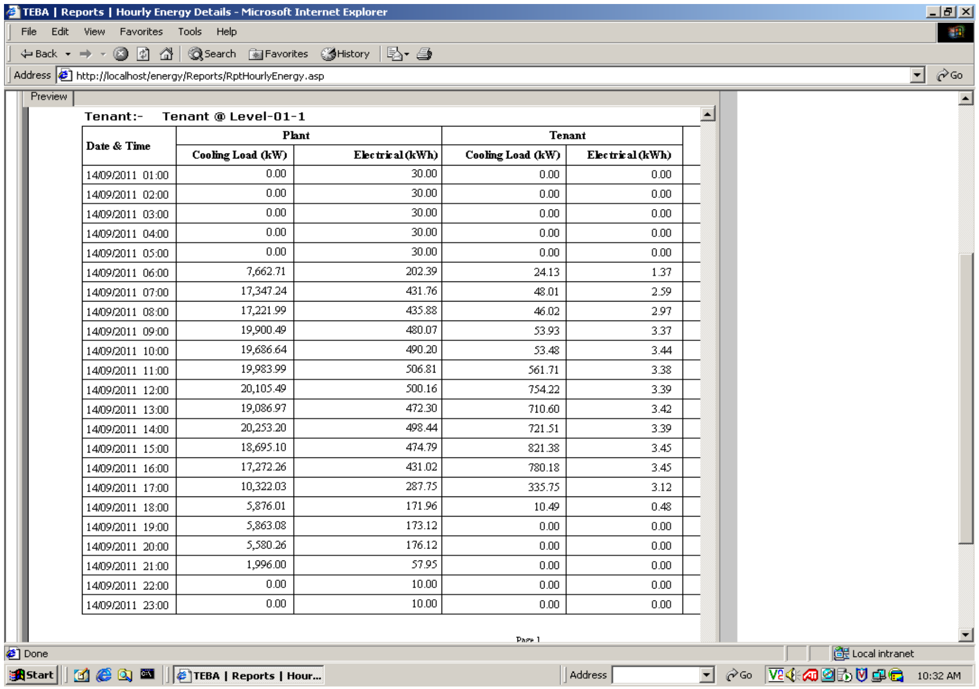
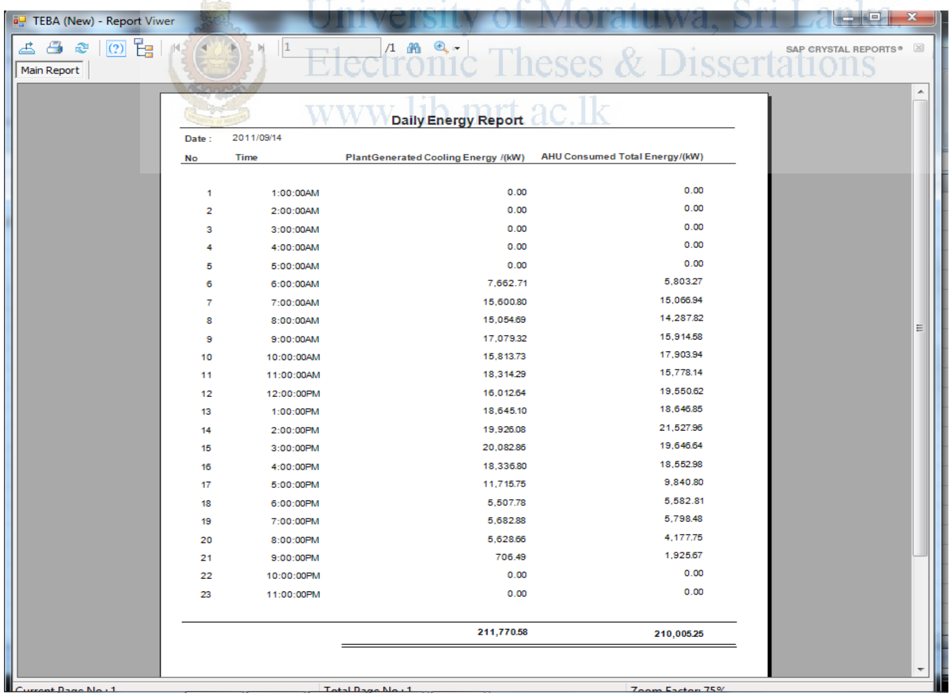
Figure 6.3: New System Hourly Energy Data for Weekday



Tenant:- Tenant @ Level-01-1

Date & Time	Plant		Tenant	
	Cooling Load (kW)	Electrical (kWh)	Cooling Load (kW)	Electrical (kWh)
14/09/2011 01:00	0.00	30.00	0.00	0.00
14/09/2011 02:00	0.00	30.00	0.00	0.00
14/09/2011 03:00	0.00	30.00	0.00	0.00
14/09/2011 04:00	0.00	30.00	0.00	0.00
14/09/2011 05:00	0.00	30.00	0.00	0.00
14/09/2011 06:00	7,662.71	202.39	24.13	1.37
14/09/2011 07:00	17,347.24	431.76	48.01	2.59
14/09/2011 08:00	17,221.99	435.88	46.02	2.97
14/09/2011 09:00	19,900.49	480.07	53.93	3.37
14/09/2011 10:00	19,686.64	490.20	53.48	3.44
14/09/2011 11:00	19,983.99	506.81	561.71	3.38
14/09/2011 12:00	20,105.49	500.16	754.22	3.39
14/09/2011 13:00	19,086.97	472.30	710.60	3.42
14/09/2011 14:00	20,253.20	498.44	721.51	3.39
14/09/2011 15:00	18,695.10	474.79	821.38	3.45
14/09/2011 16:00	17,272.26	431.02	780.18	3.45
14/09/2011 17:00	10,322.03	287.75	335.75	3.12
14/09/2011 18:00	5,876.01	171.96	10.49	0.48
14/09/2011 19:00	5,863.08	173.12	0.00	0.00
14/09/2011 20:00	5,580.26	176.12	0.00	0.00
14/09/2011 21:00	1,996.00	57.95	0.00	0.00
14/09/2011 22:00	0.00	10.00	0.00	0.00
14/09/2011 23:00	0.00	10.00	0.00	0.00

Figure 6.4: Existing System Hourly Energy Data Weekday

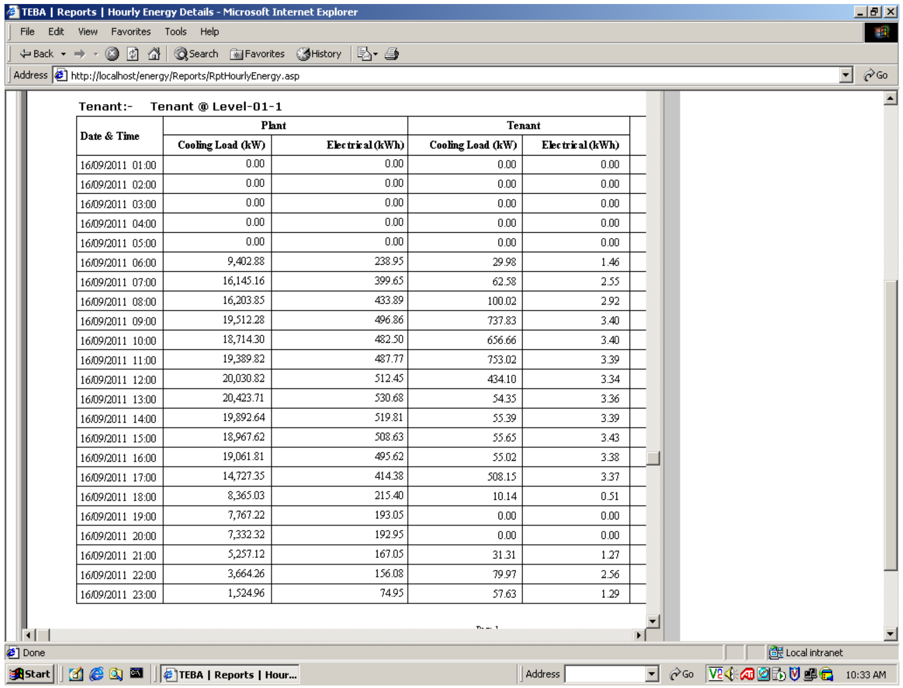


Daily Energy Report

Date : 2011/09/14

No	Time	PlantGenerated Cooling Energy /(kW)	AHU Consumed Total Energy/(kW)
1	1:00:00AM	0.00	0.00
2	2:00:00AM	0.00	0.00
3	3:00:00AM	0.00	0.00
4	4:00:00AM	0.00	0.00
5	5:00:00AM	0.00	0.00
6	6:00:00AM	7,662.71	5,803.27
7	7:00:00AM	15,600.80	15,066.94
8	8:00:00AM	15,054.69	14,287.82
9	9:00:00AM	17,079.32	15,914.58
10	10:00:00AM	15,813.73	17,903.94
11	11:00:00AM	18,314.29	15,778.14
12	12:00:00PM	16,012.64	19,550.62
13	1:00:00PM	18,645.10	18,646.85
14	2:00:00PM	19,926.08	21,527.96
15	3:00:00PM	20,082.86	19,646.64
16	4:00:00PM	18,336.80	18,552.98
17	5:00:00PM	11,715.75	9,840.80
18	6:00:00PM	5,507.78	5,582.81
19	7:00:00PM	5,682.88	5,798.48
20	8:00:00PM	5,628.66	4,177.75
21	9:00:00PM	706.49	1,925.67
22	10:00:00PM	0.00	0.00
23	11:00:00PM	0.00	0.00
		211,770.58	210,005.25

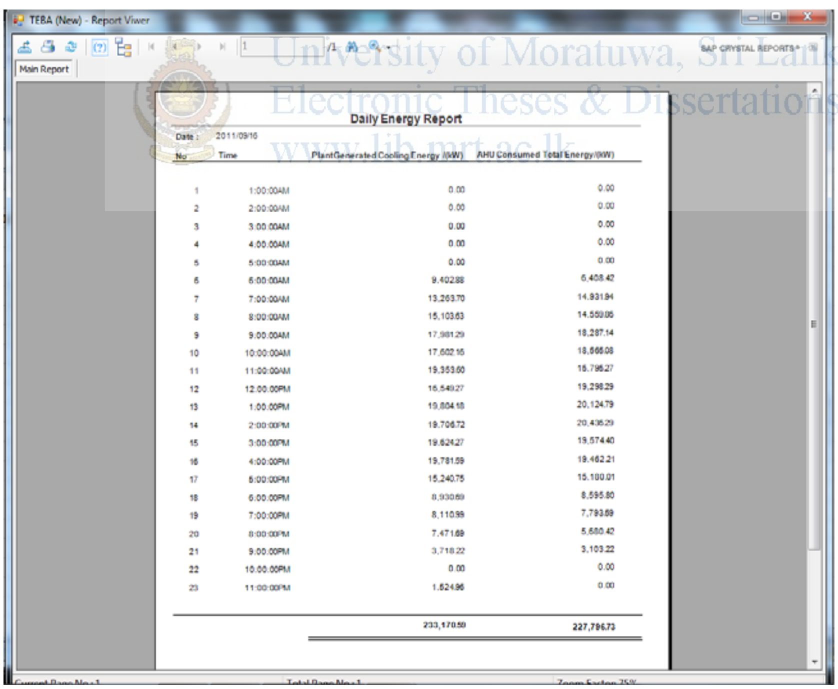
Figure 6.5: New System Hourly Energy Data Weekday



Tenant:- Tenant @ Level-01-1

Date & Time	Plant		Tenant	
	Cooling Load (kW)	Electrical (kWh)	Cooling Load (kW)	Electrical (kWh)
16/09/2011 01:00	0.00	0.00	0.00	0.00
16/09/2011 02:00	0.00	0.00	0.00	0.00
16/09/2011 03:00	0.00	0.00	0.00	0.00
16/09/2011 04:00	0.00	0.00	0.00	0.00
16/09/2011 05:00	0.00	0.00	0.00	0.00
16/09/2011 06:00	9,402.88	238.95	29.98	1.46
16/09/2011 07:00	16,145.16	399.65	62.58	2.55
16/09/2011 08:00	16,203.85	433.89	100.02	2.92
16/09/2011 09:00	19,512.28	496.86	737.83	3.40
16/09/2011 10:00	18,714.30	482.50	656.66	3.40
16/09/2011 11:00	19,389.82	487.77	753.02	3.39
16/09/2011 12:00	20,030.82	512.45	434.10	3.34
16/09/2011 13:00	20,423.71	530.68	54.35	3.36
16/09/2011 14:00	19,892.64	519.81	55.39	3.39
16/09/2011 15:00	18,967.62	508.63	55.65	3.43
16/09/2011 16:00	19,061.81	495.62	55.02	3.38
16/09/2011 17:00	14,727.35	414.38	508.15	3.37
16/09/2011 18:00	8,365.03	215.40	10.14	0.51
16/09/2011 19:00	7,767.22	193.05	0.00	0.00
16/09/2011 20:00	7,332.32	192.95	0.00	0.00
16/09/2011 21:00	5,257.12	167.05	31.31	1.27
16/09/2011 22:00	3,664.26	156.08	79.97	2.56
16/09/2011 23:00	1,524.96	74.95	57.63	1.29

Figure 6.6: Existing System Hourly Energy Data for Weekday

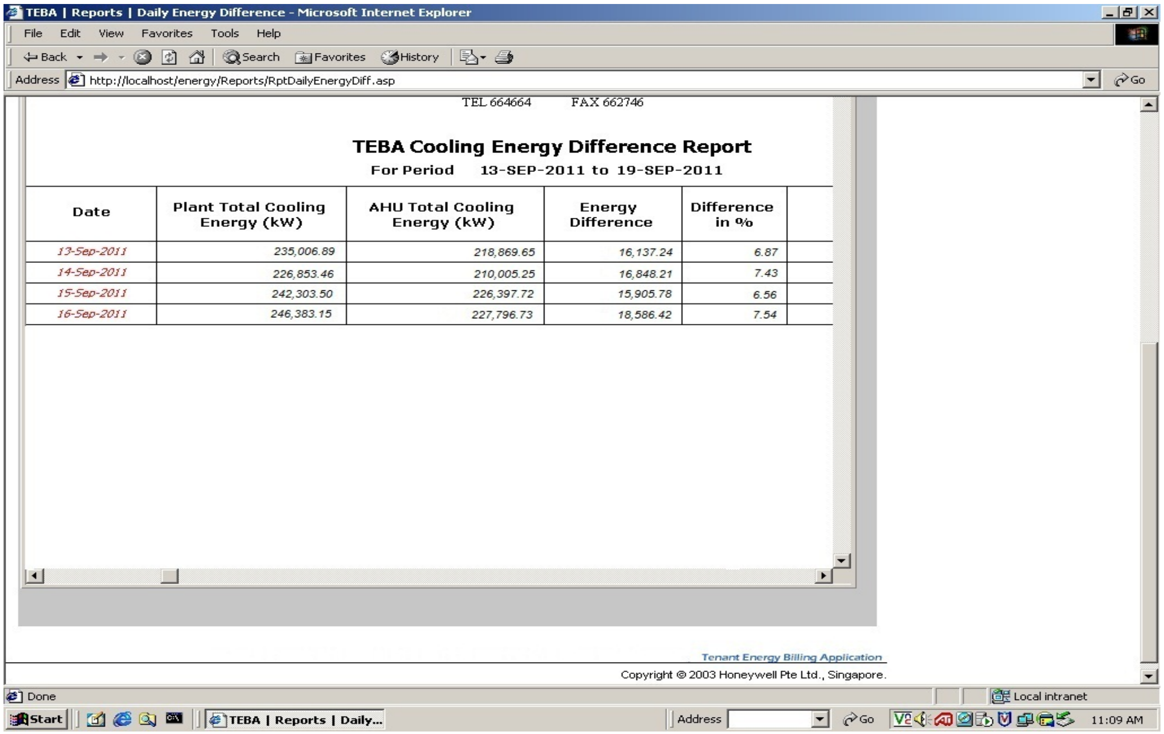


Daily Energy Report

Date : 2011/09/16

No	Time	PlantGenerated Cooling Energy /(kW)	AHU Consumed Total Energy/(kW)
1	1:00:00AM	0.00	0.00
2	2:00:00AM	0.00	0.00
3	3:00:00AM	0.00	0.00
4	4:00:00AM	0.00	0.00
5	5:00:00AM	0.00	0.00
6	6:00:00AM	9,402.88	6,408.42
7	7:00:00AM	13,263.70	14,931.84
8	8:00:00AM	15,103.63	14,559.06
9	9:00:00AM	17,981.29	18,287.14
10	10:00:00AM	17,602.16	18,666.08
11	11:00:00AM	19,353.60	16,796.27
12	12:00:00PM	16,549.27	19,298.29
13	1:00:00PM	19,804.18	20,124.79
14	2:00:00PM	19,706.72	20,436.29
15	3:00:00PM	19,624.27	19,574.40
16	4:00:00PM	19,781.59	19,462.21
17	5:00:00PM	15,240.75	15,100.01
18	6:00:00PM	8,930.69	8,595.80
19	7:00:00PM	8,110.99	7,793.69
20	8:00:00PM	7,471.69	5,680.42
21	9:00:00PM	3,718.22	3,103.22
22	10:00:00PM	0.00	0.00
23	11:00:00PM	1,524.96	0.00
		233,170.59	227,796.73

Figure 6.7: New System Hourly Energy Data for Weekday



TEBA | Reports | Daily Energy Difference - Microsoft Internet Explorer

TEL 664664 FAX 662746

TEBA Cooling Energy Difference Report

For Period 13-SEP-2011 to 19-SEP-2011

Date	Plant Total Cooling Energy (kW)	AHU Total Cooling Energy (kW)	Energy Difference	Difference in %
13-Sep-2011	235,006.89	218,869.65	16,137.24	6.87
14-Sep-2011	226,853.46	210,005.25	16,848.21	7.43
15-Sep-2011	242,303.50	226,397.72	15,905.78	6.56
16-Sep-2011	246,383.15	227,796.73	18,586.42	7.54

Tenant Energy Billing Application

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Figure 6.8: Summarized Daily Energy Data from Excising System

7. CONCLUSIONS AND RECOMMENDATIONS

Using the developed chilled water cooling energy Billing Algorithm enables the designing engineer to analyze several configurations of the Centralized Chilled water Billing System with specified cooling load profile. This provides the guideline for making more smart Chilled water Energy billing system for engineering point of view through the characteristic of cooling load profile and for economic point of view through the net present value analysis. This approach provides more benefit to the Building Automation systems designing engineer as well as to the project owner since the conventional way is to real time cooling energy balancing just concentrate only without Cooling energy loss of the distribution and stored energy in the system .These Chilled water cooling energy Billing correction method gain more and more important role when the system is getting larger and larger, especially when one mentions about the district cooling plant.

The research in based on analyzing cooling energy generation & consumption of cooling energy profile on the selected building. The analyzing the data identitified main load pattern of the building and cooling energy calculation methods. The building operation in full load conditioning (Working day) and operation in partial load condition (Week end) the load behaviors are identified major phenomena of the system.

When designing of the centralized cooling energy billing system designer shall consider thus two system pheromones and shall included the correction methods of calculation for introduced more smart billing system for building owner and tenant cooling energy users.

The research is mainly focus for error correction for full load condition energy billing with cooling energy distribution loss and stored system cooling energy corrections.

The cooling energy distribution loss from the piping network is one uncountable valve and the stored energy component is other uncountable cooling energy valve of the system to be required correction with factors to be generated to smart automated energy bill through the BAS application.

The cooling energy distribution loss through the system is depend on system capacity, geometrical location, Climate conditions, Chilled water Inlet Outlet temperature & Flow rate etc. Because of theoretical calculation of the distribution loss is not practical for billing applications so the research applied experimental loss estimation method for find out the correction factors for the cooling energy loss.

Date (Aug 2009)	Plant Generated Cooling Energy (kWh)	AHU Consumed Cooling Energy (kWh)	Corrected Plant Generated Cooling Energy (kWh)	Percentage of Cooling energy distribution loss (%)
3	285,775.06	265,602.82	276,282.90	0.98
4	259,235.77	240,687.72	250,620.35	1.08
5	107,527.29	98,090.30	103,745.01	2.61
6	253,021.43	238,652.40	248,523.97	1.09
7	246,909.89	230,109.87	239,725.17	1.13
10	262,709.11	243,021.27	253,023.91	1.07
11	207,671.26	192,356.00	200,838.68	1.35
12	228,706.40	212,902.21	222,001.28	1.22
13	231,468.12	217,484.81	226,721.35	1.20
14	221,648.46	206,584.36	215,493.89	1.26
17	238,066.86	221,309.91	230,661.21	1.18
18	234,738.53	222,121.50	231,497.15	1.17
19	224,771.45	206,988.22	215,909.87	1.26
20	229,115.57	214,338.28	223,480.43	1.21
21	201,546.86	186,419.77	194,724.36	1.39
24	239,587.72	220,645.25	229,976.61	1.18
25	218,769.75	200,066.71	208,780.71	1.30

26	210,455.01	191,666.30	200,128.29	1.36
27	215,473.80	199,195.65	207,883.52	1.30
28	206,300.10	188,925.17	197,304.93	1.37

Table 7.1: Cooling Energy Distribution Loss

As the illustration of the Table 7.1 the monthly average daily percentage of cooling energy loss in full load condition is 1.29% of the actual amount of cooling energy production from the system.

The cooling energy correction for stored cooling energy from the system is uncountable & immeasurable energy component of chilled water distribution systems. To calculate those energy component used the algorithm illustrate in the Figure 6.1. This algorithm also valid for full load condition chilled water systems.

According to the result table in Table 6.3 the monthly average daily cooling energy billing correction is nearly 44% from the excising system energy error valve.

The result is based on monthly system data analyzing method. That is valid for Sri lankan building TEBA systems because of there is no identifiable climate changes through the year. If applying the cooling energy billing correction in another location in any country with climate seasons that must analyze the data for each seasons & need to introduced sub correction factors for their climate seasonal conditioning changes.

Using research data and analyzing can be suggested following further implementations to the TEBA billing systems.

1. Introduced loss correction factors for the partial load conditions for week end & holiday application.
2. Introduced stored cooling energy correction factors for the partial load conditions for week end & holiday application.
3. Introduced correction factors for Instrumentation sensitivity & Accuracy.
4. Introduced distribution cooling energy loss distribution strategy as the,

Proportional to the cooling energy consumption

According to the operational schedule

Tenant location or Elevation

To introduced more and more correction factors for the centralized cooling energy billing system to reach more and smarter for building owner & tenants.

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APPENDIX A: Hourly Energy Data 2009 September

Date & Time	Plant Generated Cooling Energy (kWh)	Total AHU Consumed Cooling Energy (kWh)
01/08/2009 15:00	3,628.27	1,560.32
01/08/2009 16:00	4,437.49	3,920.54
01/08/2009 17:00	2,152.62	1,132.46
01/08/2009 18:00	577.63	239.12
01/08/2009 19:00	524.07	327.45
01/08/2009 20:00	507.79	268.27
01/08/2009 21:00	594.69	289.95
01/08/2009 22:00	7,031.44	4,307.64
01/08/2009 23:00	2,498.19	1,405.35
02/08/2009 01:00	522.43	295.16
02/08/2009 02:00	502.56	313.39
02/08/2009 03:00	473.95	258.12
02/08/2009 04:00	886.96	226.37
02/08/2009 05:00	5,094.90	2,096.37
02/08/2009 06:00	981.78	252.65
02/08/2009 07:00	25.35	84.01
02/08/2009 08:00	2,864.43	2,130.92
02/08/2009 09:00	5,499.15	2,947.67
02/08/2009 10:00	1,454.86	1,015.59
02/08/2009 11:00	686.51	199.66
02/08/2009 12:00	555.58	272.54
02/08/2009 13:00	509.49	215.32
02/08/2009 14:00	472.57	138.28
02/08/2009 15:00	559.76	53.95
02/08/2009 16:00	4,585.41	2,008.25
02/08/2009 17:00	1,341.11	582.13
02/08/2009 18:00	902.40	253.09
02/08/2009 19:00	542.00	176.07
02/08/2009 20:00	4,228.56	2,119.24
02/08/2009 21:00	1,861.76	1,223.98
02/08/2009 22:00	614.12	200.34
02/08/2009 23:00	1,943.59	648.67
03/08/2009 01:00	564.80	236.14
03/08/2009 02:00	528.80	364.74

03/08/2009 03:00	508.29	313.77
03/08/2009 04:00	493.06	253.65
03/08/2009 05:00	7,232.69	4,517.08
03/08/2009 06:00	11,214.98	7,422.45
03/08/2009 07:00	19,283.07	16,277.14
03/08/2009 08:00	19,841.67	17,004.22
03/08/2009 09:00	18,960.34	16,524.92
03/08/2009 10:00	19,863.78	19,461.69
03/08/2009 11:00	21,921.80	24,797.66
03/08/2009 12:00	21,516.40	23,888.64
03/08/2009 13:00	20,853.36	21,834.62
03/08/2009 14:00	19,803.50	24,419.64
03/08/2009 15:00	19,773.80	24,589.59
03/08/2009 16:00	18,723.20	21,756.85
03/08/2009 17:00	15,420.92	18,336.74
03/08/2009 18:00	8,005.49	10,911.54
03/08/2009 19:00	7,010.43	11,150.54
03/08/2009 20:00	6,215.31	8,629.22
03/08/2009 21:00	6,124.97	11,277.78
03/08/2009 22:00	1,121.65	1,615.61
03/08/2009 23:00	620.51	190.83
04/08/2009 01:00	518.25	286.15
04/08/2009 02:00	494.66	258.98
04/08/2009 03:00	2,336.44	767.44
04/08/2009 04:00	3,852.04	2,256.46
04/08/2009 05:00	588.62	299.52
04/08/2009 06:00	9,115.16	5,176.78
04/08/2009 07:00	15,924.06	14,132.26
04/08/2009 08:00	16,660.16	15,068.67
04/08/2009 09:00	17,346.57	14,945.97
04/08/2009 10:00	17,523.46	18,143.14
04/08/2009 11:00	19,191.94	24,960.41
04/08/2009 12:00	18,484.67	19,031.83
04/08/2009 13:00	18,588.10	21,190.65
04/08/2009 14:00	18,209.86	20,759.98
04/08/2009 15:00	18,000.64	20,820.64
04/08/2009 16:00	17,677.66	21,900.02
04/08/2009 17:00	16,142.22	19,330.04
04/08/2009 18:00	7,792.19	9,493.72

04/08/2009 19:00	7,355.78	9,764.02
04/08/2009 20:00	6,958.63	9,759.60
04/08/2009 21:00	5,373.55	8,661.98
04/08/2009 22:00	1,987.08	1,998.66
04/08/2009 23:00	565.98	228.85
05/08/2009 01:00	519.99	305.76
05/08/2009 02:00	499.23	280.63
05/08/2009 03:00	473.52	249.40
05/08/2009 04:00	455.22	208.87
05/08/2009 05:00	3,411.82	1,234.43
05/08/2009 06:00	3,196.53	2,493.58
05/08/2009 07:00	1,036.53	990.69
05/08/2009 08:00	5,693.00	2,742.23
05/08/2009 09:00	6,737.39	4,390.62
05/08/2009 10:00	6,386.11	4,226.96
05/08/2009 11:00	6,685.27	4,759.51
05/08/2009 12:00	7,234.81	6,921.00
05/08/2009 13:00	7,607.10	11,016.91
05/08/2009 14:00	5,688.28	8,679.69
05/08/2009 15:00	5,728.93	9,525.30
05/08/2009 16:00	5,467.85	9,306.28
05/08/2009 17:00	5,379.90	7,718.54
05/08/2009 18:00	5,221.99	6,975.20
05/08/2009 19:00	4,922.28	6,569.60
05/08/2009 20:00	4,653.78	6,442.27
05/08/2009 21:00	5,496.98	7,267.55
05/08/2009 22:00	4,350.63	4,185.79
05/08/2009 23:00	1,243.16	1,036.48
06/08/2009 01:00	549.74	329.99
06/08/2009 02:00	517.62	310.44
06/08/2009 03:00	1,317.24	683.83
06/08/2009 04:00	2,951.53	1,506.87
06/08/2009 05:00	636.59	334.62
06/08/2009 06:00	3,666.79	2,637.51
06/08/2009 07:00	19,954.44	16,535.34
06/08/2009 08:00	17,952.03	16,394.47
06/08/2009 09:00	17,499.29	15,518.41
06/08/2009 10:00	18,207.05	18,535.07
06/08/2009 11:00	19,832.60	24,688.10

06/08/2009 12:00	18,950.56	20,379.13
06/08/2009 13:00	18,551.93	20,502.82
06/08/2009 14:00	19,164.48	21,540.76
06/08/2009 15:00	18,349.07	19,916.72
06/08/2009 16:00	17,852.77	18,602.79
06/08/2009 17:00	12,497.17	13,046.82
06/08/2009 18:00	8,434.33	10,384.25
06/08/2009 19:00	7,126.98	10,810.94
06/08/2009 20:00	6,507.60	9,546.57
06/08/2009 21:00	5,940.38	8,603.70
06/08/2009 22:00	1,379.79	1,961.83
06/08/2009 23:00	812.42	250.45
07/08/2009 01:00	538.62	333.33
07/08/2009 02:00	508.80	285.57
07/08/2009 03:00	3,404.53	789.62
07/08/2009 04:00	970.68	346.41
07/08/2009 05:00	521.72	387.87
07/08/2009 06:00	8,605.01	4,791.86
07/08/2009 07:00	17,169.19	15,513.08
07/08/2009 08:00	16,670.94	14,983.86
07/08/2009 09:00	16,812.90	15,337.93
07/08/2009 10:00	17,674.53	17,948.16
07/08/2009 11:00	19,079.19	23,598.86
07/08/2009 12:00	18,506.03	20,769.13
07/08/2009 13:00	18,204.37	20,090.64
07/08/2009 14:00	17,862.65	19,603.21
07/08/2009 15:00	16,353.58	18,597.02
07/08/2009 16:00	15,449.41	18,973.47
07/08/2009 17:00	13,978.65	17,700.51
07/08/2009 18:00	7,206.22	9,830.12
07/08/2009 19:00	6,128.09	8,122.65
07/08/2009 20:00	6,010.69	7,742.43
07/08/2009 21:00	4,768.61	7,655.90
07/08/2009 22:00	2,964.73	3,283.12
07/08/2009 23:00	720.73	225.14
08/08/2009 01:00	528.94	107.37
08/08/2009 02:00	502.95	73.82
08/08/2009 03:00	4,428.25	2,862.57
08/08/2009 04:00	1,696.50	1,194.05

08/08/2009 05:00	570.67	170.79
08/08/2009 06:00	519.21	132.85
08/08/2009 07:00	510.87	98.71
08/08/2009 08:00	4,071.11	1,639.37
08/08/2009 09:00	4,155.15	2,625.66
08/08/2009 10:00	5,171.27	3,426.05
08/08/2009 11:00	4,903.96	3,491.34
08/08/2009 12:00	4,704.94	3,282.02
08/08/2009 13:00	4,517.92	3,192.14
08/08/2009 14:00	4,523.72	3,174.09
08/08/2009 15:00	4,357.77	2,885.83
08/08/2009 16:00	1,657.30	773.93
08/08/2009 17:00	653.45	123.65
08/08/2009 18:00	562.50	82.35
08/08/2009 19:00	939.52	428.67
08/08/2009 20:00	6,117.41	4,413.51
08/08/2009 21:00	3,898.51	3,107.68
08/08/2009 22:00	1,453.84	884.00
08/08/2009 23:00	663.14	168.52
09/08/2009 01:00	515.62	97.01
09/08/2009 02:00	5,268.10	3,329.18
09/08/2009 03:00	2,878.43	2,111.15
09/08/2009 04:00	830.56	209.66
09/08/2009 05:00	534.84	171.55
09/08/2009 06:00	528.98	132.84
09/08/2009 07:00	509.70	110.66
09/08/2009 08:00	1,079.40	128.16
09/08/2009 09:00	6,740.79	3,384.18
09/08/2009 10:00	2,969.74	1,854.18
09/08/2009 11:00	943.09	252.96
09/08/2009 12:00	533.02	176.38
09/08/2009 13:00	529.92	121.92
09/08/2009 14:00	533.17	149.51
09/08/2009 15:00	5,346.49	1,690.59
09/08/2009 16:00	738.49	191.50
09/08/2009 17:00	630.29	196.79
09/08/2009 18:00	538.97	135.23
09/08/2009 19:00	517.97	92.55
09/08/2009 20:00	6,697.58	2,970.51

09/08/2009 21:00	2,825.50	1,394.53
09/08/2009 22:00	631.20	173.79
09/08/2009 23:00	575.37	130.55
10/08/2009 01:00	496.58	47.66
10/08/2009 02:00	461.35	39.47
10/08/2009 03:00	5,205.93	2,909.86
10/08/2009 04:00	2,589.31	1,767.27
10/08/2009 05:00	637.06	197.50
10/08/2009 06:00	7,338.29	3,656.21
10/08/2009 07:00	22,104.60	19,094.75
10/08/2009 08:00	20,984.86	19,040.61
10/08/2009 09:00	20,510.31	18,477.32
10/08/2009 10:00	20,990.53	21,077.16
10/08/2009 11:00	22,093.50	25,617.71
10/08/2009 12:00	21,277.28	23,438.25
10/08/2009 13:00	21,004.02	24,571.74
10/08/2009 14:00	20,995.03	23,466.26
10/08/2009 15:00	18,521.46	22,478.04
10/08/2009 16:00	20,754.24	24,343.07
10/08/2009 17:00	17,121.98	16,843.69
10/08/2009 18:00	7,640.78	4,312.62
10/08/2009 19:00	7,376.71	4,550.07
10/08/2009 20:00	6,812.60	3,707.90
10/08/2009 21:00	5,860.38	2,374.81
10/08/2009 22:00	1,594.90	524.92
10/08/2009 23:00	649.57	172.22
11/08/2009 01:00	2,819.75	893.59
11/08/2009 02:00	1,074.16	480.07
11/08/2009 03:00	897.70	201.69
11/08/2009 04:00	582.21	141.06
11/08/2009 05:00	4,501.28	2,053.96
11/08/2009 06:00	8,096.17	5,714.72
11/08/2009 07:00	18,254.63	16,521.29
11/08/2009 08:00	17,700.03	16,209.31
11/08/2009 09:00	17,811.47	16,478.67
11/08/2009 10:00	18,581.04	16,405.16
11/08/2009 11:00	20,389.92	17,765.78
11/08/2009 12:00	19,296.71	16,816.50
11/08/2009 13:00	19,305.34	17,277.42

11/08/2009 14:00	18,874.63	16,950.59
11/08/2009 15:00	18,311.98	16,205.92
11/08/2009 16:00	17,820.39	15,857.81
11/08/2009 17:00	15,311.73	12,895.97
11/08/2009 18:00	8,784.14	6,054.58
11/08/2009 19:00	7,709.71	5,194.21
11/08/2009 20:00	6,697.70	4,306.67
11/08/2009 21:00	5,449.00	2,631.33
11/08/2009 22:00	1,224.74	454.75
11/08/2009 23:00	612.30	160.21
12/08/2009 01:00	506.15	86.88
12/08/2009 02:00	486.74	52.83
12/08/2009 03:00	5,166.90	2,705.15
12/08/2009 04:00	896.27	182.10
12/08/2009 05:00	506.55	132.80
12/08/2009 06:00	8,969.49	5,456.33
12/08/2009 07:00	15,578.93	14,779.94
12/08/2009 08:00	15,142.00	14,715.31
12/08/2009 09:00	15,819.86	15,057.49
12/08/2009 10:00	16,890.44	15,650.60
12/08/2009 11:00	18,526.20	16,784.65
12/08/2009 12:00	18,202.47	16,373.41
12/08/2009 13:00	18,166.28	16,240.12
12/08/2009 14:00	17,801.37	15,687.96
12/08/2009 15:00	16,641.59	14,483.83
12/08/2009 16:00	17,117.21	14,677.41
12/08/2009 17:00	14,447.83	12,034.66
12/08/2009 18:00	7,374.15	4,850.49
12/08/2009 19:00	6,759.29	4,928.12
12/08/2009 20:00	6,334.09	4,503.46
12/08/2009 21:00	5,385.16	2,833.70
12/08/2009 22:00	1,347.64	516.62
12/08/2009 23:00	639.79	168.35
13/08/2009 01:00	515.77	83.95
13/08/2009 02:00	5,875.33	3,644.36
13/08/2009 03:00	1,698.62	896.31
13/08/2009 04:00	612.89	152.06
13/08/2009 05:00	536.41	113.26
13/08/2009 06:00	9,728.52	6,608.23

13/08/2009 07:00	14,287.80	13,444.19
13/08/2009 08:00	15,192.52	14,636.32
13/08/2009 09:00	16,216.42	15,337.75
13/08/2009 10:00	17,647.24	16,027.88
13/08/2009 11:00	17,976.33	16,543.12
13/08/2009 12:00	17,901.69	16,188.28
13/08/2009 13:00	17,551.21	15,553.80
13/08/2009 14:00	17,348.65	15,476.27
13/08/2009 15:00	17,430.16	15,283.54
13/08/2009 16:00	17,561.98	15,404.89
13/08/2009 17:00	14,996.52	12,926.34
13/08/2009 18:00	8,780.90	6,304.41
13/08/2009 19:00	7,242.51	5,178.40
13/08/2009 20:00	6,028.72	3,891.43
13/08/2009 21:00	4,868.78	2,604.09
13/08/2009 22:00	872.87	1,009.03
13/08/2009 23:00	596.28	176.90
14/08/2009 01:00	512.55	83.20
14/08/2009 02:00	488.33	54.19
14/08/2009 03:00	458.94	45.18
14/08/2009 04:00	443.56	47.29
14/08/2009 05:00	3,285.39	886.84
14/08/2009 06:00	9,544.94	6,222.09
14/08/2009 07:00	14,003.15	12,052.08
14/08/2009 08:00	14,410.92	13,007.33
14/08/2009 09:00	15,724.39	13,736.44
14/08/2009 10:00	16,432.34	14,354.98
14/08/2009 11:00	17,947.59	15,688.04
14/08/2009 12:00	18,026.92	15,608.99
14/08/2009 13:00	18,174.83	15,830.24
14/08/2009 14:00	18,738.37	16,085.94
14/08/2009 15:00	16,918.93	14,205.02
14/08/2009 16:00	16,536.78	13,783.41
14/08/2009 17:00	9,367.23	7,011.74
14/08/2009 18:00	6,026.72	3,850.00
14/08/2009 19:00	6,633.43	4,619.09
14/08/2009 20:00	6,203.56	4,136.92
14/08/2009 21:00	5,002.96	2,528.06
14/08/2009 22:00	3,591.11	1,668.09

14/08/2009 23:00	3,175.52	1,079.20
15/08/2009 01:00	1,149.50	347.47
15/08/2009 02:00	632.54	135.52
15/08/2009 03:00	541.77	108.47
15/08/2009 04:00	509.54	76.49
15/08/2009 05:00	490.30	54.68
15/08/2009 06:00	466.57	34.84
15/08/2009 07:00	449.76	37.32
15/08/2009 08:00	3,142.85	456.61
15/08/2009 09:00	5,390.97	3,115.11
15/08/2009 10:00	5,640.71	4,783.36
15/08/2009 11:00	6,640.59	6,244.42
15/08/2009 12:00	6,704.36	5,639.71
15/08/2009 13:00	6,315.24	5,537.96
15/08/2009 14:00	3,946.72	3,388.72
15/08/2009 15:00	6,607.53	5,113.72
15/08/2009 16:00	6,009.32	4,727.06
15/08/2009 17:00	5,047.71	2,802.08
15/08/2009 18:00	2,679.50	1,218.83
15/08/2009 19:00	414.28	165.53
15/08/2009 20:00	646.83	148.48
15/08/2009 21:00	566.52	97.18
15/08/2009 22:00	520.07	52.02
15/08/2009 23:00	502.39	38.16
16/08/2009 01:00	4,366.52	969.89
16/08/2009 02:00	1,015.26	199.92
16/08/2009 03:00	527.99	125.49
16/08/2009 04:00	516.89	79.34
16/08/2009 05:00	491.80	53.93
16/08/2009 06:00	5,640.24	2,261.74
16/08/2009 07:00	0.00	69.73
16/08/2009 08:00	1,012.13	191.60
16/08/2009 09:00	567.36	123.61
16/08/2009 10:00	4,163.29	1,949.90
16/08/2009 11:00	6,506.77	5,032.88
16/08/2009 12:00	4,736.25	3,692.20
16/08/2009 13:00	2,825.72	1,901.35
16/08/2009 14:00	558.71	176.19
16/08/2009 15:00	548.01	133.10

16/08/2009 16:00	524.07	86.66
16/08/2009 17:00	486.60	66.12
16/08/2009 18:00	461.86	67.00
16/08/2009 19:00	5,100.77	1,943.14
16/08/2009 20:00	3,289.55	1,366.41
16/08/2009 21:00	956.25	231.72
16/08/2009 22:00	601.85	172.75
16/08/2009 23:00	2,424.85	743.23
17/08/2009 01:00	559.94	94.14
17/08/2009 02:00	530.79	49.25
17/08/2009 03:00	6,499.08	3,669.74
17/08/2009 04:00	3,286.36	1,749.54
17/08/2009 05:00	576.56	122.78
17/08/2009 06:00	8,606.42	5,217.49
17/08/2009 07:00	20,126.76	16,187.56
17/08/2009 08:00	18,639.53	15,515.51
17/08/2009 09:00	18,359.98	14,826.97
17/08/2009 10:00	18,166.68	14,910.59
17/08/2009 11:00	19,157.22	16,112.77
17/08/2009 12:00	19,393.11	16,148.76
17/08/2009 13:00	18,263.36	14,848.22
17/08/2009 14:00	17,844.77	14,208.68
17/08/2009 15:00	17,420.89	13,647.94
17/08/2009 16:00	17,161.50	13,506.36
17/08/2009 17:00	11,983.27	8,702.39
17/08/2009 18:00	5,116.32	2,759.52
17/08/2009 19:00	5,371.07	3,355.29
17/08/2009 20:00	5,258.26	3,308.22
17/08/2009 21:00	4,033.09	1,872.56
17/08/2009 22:00	1,085.68	359.72
17/08/2009 23:00	626.22	135.91
18/08/2009 01:00	508.25	43.30
18/08/2009 02:00	482.86	12.91
18/08/2009 03:00	3,243.90	886.24
18/08/2009 04:00	1,521.61	802.72
18/08/2009 05:00	613.02	97.69
18/08/2009 06:00	10,508.52	6,380.57
18/08/2009 07:00	14,631.14	12,507.38
18/08/2009 08:00	15,729.22	13,282.65

18/08/2009 09:00	15,852.11	13,182.17
18/08/2009 10:00	17,352.60	14,048.26
18/08/2009 11:00	18,232.91	14,853.99
18/08/2009 12:00	18,372.71	15,038.82
18/08/2009 13:00	18,348.57	15,044.64
18/08/2009 14:00	18,299.48	15,376.86
18/08/2009 15:00	17,052.83	13,863.63
18/08/2009 16:00	16,577.95	13,189.01
18/08/2009 17:00	13,709.75	10,603.74
18/08/2009 18:00	9,514.65	6,583.42
18/08/2009 19:00	8,535.87	6,463.61
18/08/2009 20:00	7,441.10	5,385.48
18/08/2009 21:00	6,469.33	3,895.78
18/08/2009 22:00	1,001.29	413.34
18/08/2009 23:00	738.86	165.29
19/08/2009 01:00	500.71	27.13
19/08/2009 02:00	487.12	13.87
19/08/2009 03:00	3,462.54	749.93
19/08/2009 04:00	911.34	110.81
19/08/2009 05:00	537.66	58.38
19/08/2009 06:00	8,387.03	4,961.21
19/08/2009 07:00	14,180.04	12,120.65
19/08/2009 08:00	15,257.23	13,110.86
19/08/2009 09:00	17,091.85	13,867.02
19/08/2009 10:00	17,629.48	14,499.90
19/08/2009 11:00	18,165.71	14,918.48
19/08/2009 12:00	17,840.34	14,765.61
19/08/2009 13:00	17,868.09	14,656.01
19/08/2009 14:00	18,421.92	14,930.39
19/08/2009 15:00	17,836.29	14,327.89
19/08/2009 16:00	16,698.41	13,573.74
19/08/2009 17:00	13,728.69	10,776.25
19/08/2009 18:00	6,582.40	4,448.67
19/08/2009 19:00	6,360.51	4,379.58
19/08/2009 20:00	5,406.83	3,768.70
19/08/2009 21:00	4,599.65	2,851.56
19/08/2009 22:00	2,266.62	941.51
19/08/2009 23:00	550.99	130.07
20/08/2009 01:00	492.79	21.25

20/08/2009 02:00	476.38	3.41
20/08/2009 03:00	6,324.28	3,568.57
20/08/2009 04:00	946.50	121.05
20/08/2009 05:00	513.50	60.68
20/08/2009 06:00	7,989.11	4,481.77
20/08/2009 07:00	14,024.00	12,119.61
20/08/2009 08:00	15,042.72	12,763.62
20/08/2009 09:00	16,992.43	13,789.63
20/08/2009 10:00	17,086.93	13,981.22
20/08/2009 11:00	17,989.64	15,073.14
20/08/2009 12:00	17,824.04	14,921.60
20/08/2009 13:00	16,793.07	13,793.60
20/08/2009 14:00	18,181.85	14,962.20
20/08/2009 15:00	17,688.08	14,434.95
20/08/2009 16:00	16,149.76	13,277.39
20/08/2009 17:00	14,544.96	11,674.89
20/08/2009 18:00	8,813.76	6,098.05
20/08/2009 19:00	7,730.20	5,849.40
20/08/2009 20:00	5,662.26	3,939.97
20/08/2009 21:00	4,869.35	2,521.64
20/08/2009 22:00	2,234.13	771.06
20/08/2009 23:00	745.83	109.58
21/08/2009 01:00	506.12	21.41
21/08/2009 02:00	480.67	1.58
21/08/2009 03:00	3,939.43	2,003.57
21/08/2009 04:00	850.55	125.22
21/08/2009 05:00	493.40	51.27
21/08/2009 06:00	8,777.77	5,416.07
21/08/2009 07:00	12,186.90	10,458.24
21/08/2009 08:00	13,193.58	12,097.61
21/08/2009 09:00	14,343.83	12,834.90
21/08/2009 10:00	15,128.05	13,034.02
21/08/2009 11:00	16,703.22	14,201.88
21/08/2009 12:00	16,126.98	13,738.11
21/08/2009 13:00	16,897.00	14,040.97
21/08/2009 14:00	16,490.52	13,813.61
21/08/2009 15:00	15,702.87	13,071.14
21/08/2009 16:00	14,740.54	12,191.71
21/08/2009 17:00	12,817.18	10,142.22

21/08/2009 18:00	5,679.30	3,581.34
21/08/2009 19:00	5,000.02	3,330.03
21/08/2009 20:00	5,377.13	3,478.92
21/08/2009 21:00	4,070.92	2,198.57
21/08/2009 22:00	1,520.52	481.60
21/08/2009 23:00	520.36	105.78
22/08/2009 01:00	488.74	50.98
22/08/2009 02:00	470.00	34.26
22/08/2009 03:00	462.08	34.95
22/08/2009 04:00	440.65	37.44
22/08/2009 05:00	5,037.99	2,144.79
22/08/2009 06:00	1,741.01	673.94
22/08/2009 07:00	605.31	106.22
22/08/2009 08:00	491.04	62.05
22/08/2009 09:00	832.14	81.37
22/08/2009 10:00	6,935.88	4,968.39
22/08/2009 11:00	4,562.31	3,834.40
22/08/2009 12:00	4,576.67	3,640.62
22/08/2009 13:00	4,232.71	3,199.18
22/08/2009 14:00	4,223.29	3,138.86
22/08/2009 15:00	3,937.94	2,794.27
22/08/2009 16:00	1,091.22	509.55
22/08/2009 17:00	618.13	139.61
22/08/2009 18:00	524.56	85.15
22/08/2009 19:00	485.65	58.84
22/08/2009 20:00	459.33	60.13
22/08/2009 21:00	440.13	61.04
22/08/2009 22:00	3,894.02	1,039.56
22/08/2009 23:00	3,144.25	1,411.65
23/08/2009 01:00	619.72	130.68
23/08/2009 02:00	524.57	85.29
23/08/2009 03:00	480.13	65.52
23/08/2009 04:00	450.85	66.31
23/08/2009 05:00	4,391.17	1,951.46
23/08/2009 06:00	1,192.77	456.67
23/08/2009 07:00	783.45	172.30
23/08/2009 08:00	673.40	450.55
23/08/2009 09:00	5,721.75	2,464.67
23/08/2009 10:00	3,596.45	2,202.44

23/08/2009 11:00	3,522.98	2,094.36
23/08/2009 12:00	1,645.19	741.05
23/08/2009 13:00	590.89	95.92
23/08/2009 14:00	515.44	52.89
23/08/2009 15:00	497.49	36.33
23/08/2009 16:00	4,954.52	3,187.71
23/08/2009 17:00	872.02	150.86
23/08/2009 18:00	533.20	107.48
23/08/2009 19:00	508.28	66.52
23/08/2009 20:00	491.52	47.68
23/08/2009 21:00	468.22	49.20
23/08/2009 22:00	451.31	50.74
23/08/2009 23:00	599.79	128.81
24/08/2009 01:00	2,369.49	758.54
24/08/2009 02:00	620.86	148.86
24/08/2009 03:00	494.37	92.26
24/08/2009 04:00	510.72	62.21
24/08/2009 05:00	492.64	62.22
24/08/2009 06:00	10,027.11	5,470.18
24/08/2009 07:00	18,213.39	15,823.08
24/08/2009 08:00	17,150.56	14,965.85
24/08/2009 09:00	17,606.44	15,547.47
24/08/2009 10:00	18,449.39	15,832.16
24/08/2009 11:00	19,550.05	16,599.65
24/08/2009 12:00	18,442.76	15,513.76
24/08/2009 13:00	19,052.68	16,437.33
24/08/2009 14:00	17,346.11	14,346.65
24/08/2009 15:00	17,740.84	14,712.70
24/08/2009 16:00	17,402.79	15,140.86
24/08/2009 17:00	15,151.33	12,775.56
24/08/2009 18:00	7,848.62	4,746.69
24/08/2009 19:00	6,559.79	4,058.30
24/08/2009 20:00	6,021.49	3,562.87
24/08/2009 21:00	5,383.61	2,842.45
24/08/2009 22:00	2,414.40	950.36
24/08/2009 23:00	738.28	195.24
25/08/2009 01:00	532.27	67.01
25/08/2009 02:00	513.32	39.34
25/08/2009 03:00	493.75	36.25

25/08/2009 04:00	473.46	38.63
25/08/2009 05:00	3,806.78	1,345.78
25/08/2009 06:00	9,541.94	6,323.08
25/08/2009 07:00	14,387.66	12,348.32
25/08/2009 08:00	14,400.85	13,093.57
25/08/2009 09:00	16,511.42	15,896.95
25/08/2009 10:00	16,842.63	16,223.74
25/08/2009 11:00	17,929.88	17,021.89
25/08/2009 12:00	17,375.90	16,343.07
25/08/2009 13:00	17,164.05	15,847.95
25/08/2009 14:00	17,260.65	15,842.50
25/08/2009 15:00	17,010.54	15,671.26
25/08/2009 16:00	16,624.19	15,531.03
25/08/2009 17:00	14,083.54	13,045.60
25/08/2009 18:00	7,090.72	5,093.46
25/08/2009 19:00	5,501.57	3,647.55
25/08/2009 20:00	4,744.29	3,217.46
25/08/2009 21:00	4,761.35	3,423.17
25/08/2009 22:00	1,221.28	812.59
25/08/2009 23:00	497.71	156.51
26/08/2009 01:00	558.05	80.01
26/08/2009 02:00	760.67	180.04
26/08/2009 03:00	6,099.06	3,271.40
26/08/2009 04:00	887.47	170.09
26/08/2009 05:00	523.02	111.96
26/08/2009 06:00	7,621.77	4,487.07
26/08/2009 07:00	14,108.82	12,500.70
26/08/2009 08:00	14,047.50	12,943.10
26/08/2009 09:00	14,287.80	12,969.27
26/08/2009 10:00	16,170.17	14,220.87
26/08/2009 11:00	16,780.62	14,497.59
26/08/2009 12:00	16,367.55	13,931.40
26/08/2009 13:00	16,198.86	13,657.26
26/08/2009 14:00	16,915.78	14,462.52
26/08/2009 15:00	16,678.58	14,517.10
26/08/2009 16:00	16,005.81	14,423.15
26/08/2009 17:00	12,493.94	9,916.95
26/08/2009 18:00	7,135.73	4,782.91
26/08/2009 19:00	6,781.53	4,854.23

26/08/2009 20:00	5,810.91	3,811.32
26/08/2009 21:00	3,739.59	1,732.11
26/08/2009 22:00	0.00	18.61
26/08/2009 23:00	481.78	126.64
27/08/2009 01:00	536.81	82.56
27/08/2009 02:00	501.56	52.72
27/08/2009 03:00	476.41	43.97
27/08/2009 04:00	4,297.97	1,362.37
27/08/2009 05:00	1,452.66	522.96
27/08/2009 06:00	7,830.98	5,204.48
27/08/2009 07:00	13,567.99	11,506.32
27/08/2009 08:00	14,616.17	13,421.99
27/08/2009 09:00	16,066.59	14,583.88
27/08/2009 10:00	17,110.59	14,863.90
27/08/2009 11:00	16,836.14	14,791.22
27/08/2009 12:00	16,654.57	14,090.10
27/08/2009 13:00	16,987.16	14,501.38
27/08/2009 14:00	16,529.34	14,090.50
27/08/2009 15:00	16,483.15	14,337.91
27/08/2009 16:00	15,757.90	13,279.07
27/08/2009 17:00	12,570.81	9,977.55
27/08/2009 18:00	7,120.66	4,249.85
27/08/2009 19:00	6,257.16	4,518.87
27/08/2009 20:00	5,425.46	3,684.25
27/08/2009 21:00	5,448.34	3,652.13
27/08/2009 22:00	2,302.95	1,233.47
27/08/2009 23:00	642.43	144.20
28/08/2009 01:00	531.04	61.30
28/08/2009 02:00	511.32	39.27
28/08/2009 03:00	495.64	39.62
28/08/2009 04:00	479.15	41.92
28/08/2009 05:00	3,586.82	1,176.72
28/08/2009 06:00	8,261.18	6,147.87
28/08/2009 07:00	13,768.41	11,817.77
28/08/2009 08:00	14,599.37	13,149.67
28/08/2009 09:00	15,680.06	13,717.01
28/08/2009 10:00	16,173.80	13,674.16
28/08/2009 11:00	17,114.81	14,599.07
28/08/2009 12:00	16,187.39	13,689.36

28/08/2009 13:00	16,306.59	13,878.84
28/08/2009 14:00	16,859.67	14,451.67
28/08/2009 15:00	15,726.42	13,047.14
28/08/2009 16:00	15,237.62	12,255.21
28/08/2009 17:00	11,306.55	8,720.19
28/08/2009 18:00	6,052.08	4,700.85
28/08/2009 19:00	6,147.70	5,218.36
28/08/2009 20:00	5,397.35	4,318.82
28/08/2009 21:00	4,212.74	3,572.96
28/08/2009 22:00	1,061.66	508.25
28/08/2009 23:00	614.17	117.31
29/08/2009 01:00	519.60	43.13
29/08/2009 02:00	505.07	35.00
29/08/2009 03:00	488.92	38.09
29/08/2009 04:00	472.37	40.94
29/08/2009 05:00	457.14	43.56
29/08/2009 06:00	493.03	48.79
29/08/2009 07:00	8,107.78	4,813.53
29/08/2009 08:00	6,915.23	6,340.90
29/08/2009 09:00	4,683.59	2,984.84
29/08/2009 10:00	6,621.50	5,872.38
29/08/2009 11:00	6,060.42	5,182.58
29/08/2009 12:00	5,778.42	4,791.89
29/08/2009 13:00	5,503.21	4,480.46
29/08/2009 14:00	5,298.11	4,461.35
29/08/2009 15:00	7,215.92	6,680.53
29/08/2009 16:00	6,802.04	5,965.94
29/08/2009 17:00	3,585.34	3,088.96
29/08/2009 18:00	617.34	97.03
29/08/2009 19:00	3,624.64	1,912.17
29/08/2009 20:00	5,853.50	4,373.26
29/08/2009 21:00	5,036.18	3,430.25
29/08/2009 22:00	5,401.34	3,490.68
29/08/2009 23:00	4,145.41	2,272.00
30/08/2009 01:00	0.00	0.00
30/08/2009 02:00	0.00	0.00
30/08/2009 03:00	0.00	0.00
30/08/2009 04:00	0.00	0.00
30/08/2009 05:00	0.00	0.00

30/08/2009 06:00	0.00	0.00
30/08/2009 07:00	0.00	0.00
30/08/2009 08:00	0.00	0.00
30/08/2009 09:00	0.00	0.00
30/08/2009 10:00	0.00	0.00
30/08/2009 11:00	0.00	0.00
30/08/2009 12:00	0.00	0.00
30/08/2009 13:00	0.00	0.00
30/08/2009 14:00	0.00	0.00
30/08/2009 15:00	0.00	0.00
30/08/2009 16:00	0.00	0.00
30/08/2009 17:00	0.00	0.00
30/08/2009 18:00	0.00	0.00
30/08/2009 19:00	0.00	0.00
30/08/2009 20:00	0.00	0.00
30/08/2009 21:00	0.00	0.00
30/08/2009 22:00	0.00	0.00
30/08/2009 23:00	0.00	0.00
31/08/2009 00:00	0.00	0.00
31/08/2009 01:00	0.00	0.00
31/08/2009 02:00	0.00	0.00
31/08/2009 03:00	0.00	0.00
31/08/2009 04:00	0.00	0.00
31/08/2009 05:00	0.00	0.00
31/08/2009 06:00	0.00	0.00
31/08/2009 07:00	0.00	0.00
31/08/2009 08:00	0.00	0.00
31/08/2009 09:00	0.00	0.00
31/08/2009 10:00	0.00	0.00
31/08/2009 11:00	0.00	0.00
31/08/2009 12:00	0.00	0.00
31/08/2009 13:00	0.00	0.00
31/08/2009 14:00	0.00	0.00
31/08/2009 15:00	0.00	0.00
31/08/2009 16:00	0.00	0.00
31/08/2009 17:00	0.00	0.00
31/08/2009 18:00	0.00	0.00
31/08/2009 19:00	0.00	0.00
31/08/2009 20:00	0.00	0.00

31/08/2009 21:00	0.00	0.00
31/08/2009 22:00	0.00	0.00
31/08/2009 23:00	0.00	0.00
01/09/2009 00:00	0.00	0.00
01/09/2009 01:00	0.00	0.00
01/09/2009 02:00	0.00	0.00
01/09/2009 03:00	0.00	0.00
01/09/2009 04:00	0.00	0.00
01/09/2009 05:00	0.00	0.00
01/09/2009 06:00	0.00	0.00
01/09/2009 07:00	0.00	0.00
01/09/2009 08:00	0.00	0.00
01/09/2009 09:00	0.00	0.00
01/09/2009 10:00	0.00	0.00
01/09/2009 11:00	0.00	0.00
01/09/2009 12:00	0.00	0.00
01/09/2009 13:00	0.00	0.00
01/09/2009 14:00	0.00	0.00
01/09/2009 15:00	0.00	0.00