DEMAND SIDE MANAGEMENT FOR A CAMPUS INFRASTRUCTURE

A PROJECT REPORT

Submitted by

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ABSTRACT

Due to large industrial and overall development of the country, demand for electricity has seen to be exponentially increased during last decade. Demand side management (DSM) is one of the important functions in a grid that allows consumers to make informed decisions regarding their energy consumption, and helps the energy providers reduce the peak load demand and reshape the load profile. From the inference of our historical data, energy demand has exponentially increasing, and this could be minimized by specific algorithms. One such way is demand side management which consists of planning, implementing, and monitoring activities of electrical utilities which encourage consumers to modify their level and pattern of electricity usage, ensuring stability on the electricity grid and demand to remain in balance throughout the year. A load shifting demand side management technique is utilized here to transfer low priority consumer loads from high demand to off peak periods, which can intern reduce critical peak demand. Simulations are carried out for a university infrastructure, utilizing the existing photo-voltaic array dg generators. These existing assets are treated as a local grid and evaluated for four different operational scenarios. The results show significant cost savings are achievable with the proposed optimization strategy.

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LIST OF SYMBOLS AND ABBREVIATIONS

Abbreviations

AC	-	Alternating Current
DC	-	Direct Current
Dg	-	Diesel Generator
DP	-	Dynamic Pricing
DSM	-	Demand Side Management
EPLF	-	Electric Power Load Forecasting
GA	-	Genetic Algorithm
LDC	-	Local Distribution Company
LT	-	Low Tension
PV	-	Photovoltaic
REM	-	Residential Energy Management
ToD	-	Time of Day
ToU	-	Time-of-Use

List of Symbols:

ACP_{ac}	-	Actual Load consumption
C_m	-	Average of the prices
C_{max}	-	Maximum price
Y_{kit}	-	Number of devices shifted from time step i to t
D	-	Number of device types
P_{1k}	-	Power Consumption at time step 1
$P_{(1+l)k}$	-	Power Consumption at time step 1+l
Y_{ktq}	-	Number of devices delayed from time step t to q

m	-	Maximum allowable delay
P	-	Power in kilowatt
V	-	Voltage in volts
$\cos \phi$	-	Power factor
P_R	-	Power at R phase in Kw
P_Y	-	Power at Y phase in Kw
P_Z	-	Power at Z phase in Kw

CHAPTER 1

INTRODUCTION

1.1 POWER SYSTEM NETWORK

An electric power system is a network of electrical components used to supply, transfer and use electric power. An example of an electric power system is the network that supplies a region's homes and industry with power—for sizable regions, this power system is known as the grid and can be broadly divided into the generators that supply the power, the transmission system that carries the power from the generating centres to the load centres and the distribution system that feeds the power to nearby homes and industries. Smaller power systems are also found in industry, hospitals, commercial buildings and homes. The majority of these systems rely upon three-phase AC power—the standard for large-scale power transmission and distribution across the modern world. Specialised power systems that do not always rely upon three-phase AC power are found in aircraft, electric rail systems, ocean liners and automobiles. The ability to easily transform the voltage of AC power is important for two reasons, Firstly, power can be transmitted over long distances with less loss at higher voltages. So in power systems where generation is distant from the load, it is desirable to step-up (increase) the voltage of power at the generation point and then step-down (decrease) the voltage near the load. A typical power system network is shown in Figure 1.1.

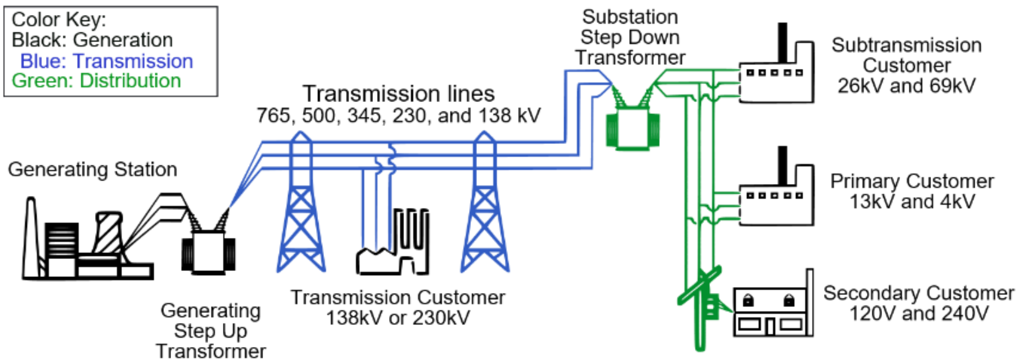


Figure 1.1 Power System Network

1.1.1 Power Generation

Power generation is the process of generating electricity from other sources of primary energy. Electricity is most often generated at a power station by electromechanical generators, primarily driven by heat engines fuelled by chemical combustion or nuclear fission but also by other means such as the kinetic energy of flowing water and wind. Other energy sources include solar photovoltaics and geothermal power and electrochemical batteries.

1.1.2 Power Transmission

Electric power transmission is the bulk transfer of electrical energy, from generating power plants to electrical substations located near demand centres. This is distinct from the local wiring between high-voltage substations and customers, which is typically referred to as electric power distribution. Transmission lines, when interconnected with each other, become transmission networks.

1.1.3 Power Distribution

Electric power distribution system is the final stage in the delivery of electric power; it carries electricity from the transmission system to individual consumers. Distribution substations connect to the transmission system and lower the transmission voltage to medium voltage ranging between 2 kV and 35 kV with the use of transformers. Primary distribution lines carry this medium voltage power to distribution transformers located near the customer's premises. Distribution transformers again lower the voltage to the utilization voltage of household appliances and typically feed several customers through secondary distribution lines at this voltage. Commercial and residential customers are connected to the secondary distribution lines through service drops. Customers demanding a much larger amount of power may be connected directly to the primary distribution level or the sub transmission level. The Power Grid Corporation of India is responsible for the inter-state transmission of electricity and the development of national grid. India is world’s 6th largest energy consumer, accounting for 3.4% of global energy consumption, with Maharashtra as the leading electricity generator among Indian states. Due to India’s economic rise, the demand for energy has grown at an average of 3.6% per annum over the past 30 years. At the end of December 2012, the installed power generation capacity of India stood at 210951.72MW, while the per capita energy consumption stood at 733.54 KWh (2008-09). The Indian government has set an ambitious target to add approximately 78,000 MW of installed generation capacity by 2012. The total demand for electricity in India is expected to cross 950,000 MW by 2030.

1.2 DEMAND SIDE MANAGEMENT

Demand Side management (DSM) adjusts electrical loads in customer's premises with respect to time and amount of their use, helping electric utility to decrease demand peak and thereby redistribute the load of the system. This aids to reduce the huge gap between peak demand and the available generation of energy during peak period. DSM is the management of loads on demand side that helps to flatten the overall load curve. Load shifting from peak to off-peak period is one of the most effective DSM strategy used to flatten the load curve. DSM encourages active participation of customers in reducing the peak demand by shifting the load according to the generation. The customers in return are rewarded in a way that they have to pay low electricity price. Reducing the consumption of energy during peak hours and scheduling the demand to low peak hours is one of the major goals of DSM. DSM can be divided in two categories as a direct load control (DLC) that permits utilities to control a part of customer's load directly with their consent and an indirect load control (IDLC), that permits customers to manage their consumption on their own as per the price signal sent by the utility. Thus shifting of customer's controllable loads in order to reduce system peak demand is an important aspect of DSM.

1.2.1 Objective of Demand Side Management

The objective of DSM is to reduce the peak electricity demand and promoting the energy efficient devices. In fact, to reduce the overall load on electrical network, total consumption and peak demand can be reduced by:

- Improving the load curve
- Energy Conservation

The DSM strategies have the objective of maximizing the end use efficiency to avoid/ postpone the requirement of new generating capacity. In DSM three concepts are clearly identified: Demand Response, Energy Efficiency and Energy Conservation.

1.2.2 Need for Demand Side Management

Various reasons are put forward for promoting or undertaking Demand Side Management.

- Cost reduction—many DSM and energy efficiency efforts have been introduced in the context of integrated resource planning and aimed at reducing total costs of meeting energy demand.
- Environmental and social improvement—energy efficiency and DSM may be pursued to achieve environmental and/or social goals by reducing energy use, leading to reduced greenhouse gas emissions;

- Reliability and network issues—ameliorating and/or averting problems in the electricity network through reducing demand in ways which maintain system reliability in the immediate term and over the longer term defer the need for network augmentation.

- Improved markets—short-term responses to electricity market conditions ("demand response"), particularly by reducing load during periods of high market prices caused by reduced generation or network capacity.

1.2.3 Demand Side Management Techniques

Demand side management alters customers' electricity consumption patterns to produce the desired changes in the load shapes of power distribution systems. The changes in the final consumption profile will depend on the planning objectives and operation of the utility companies. Demand side management focuses on utilizing power saving technologies, electricity tariffs, monetary incentives, and government policies to mitigate the peak load demand instead of enlarging the generation capacity or reinforcing the transmission and distribution network. To mitigate system instabilities brought about by increasing electricity demand, a suitable objective of demand side management activities could be to change the shape of the load demand curve by reducing the total load demand of the distribution system during peak periods, and shift these loads to be served during more appropriate times in order to reduce the overall planning and operational cost of the network. Such a scheme requires a sophisticated coordination between the network operators and customers. The load shapes which indicate the daily or seasonal electricity demands of industrial, commercial or residential consumers between peak and off peak times can be altered by means of six broad methods: peak clipping, valley filling, load shifting, strategic conservation, strategic load growth, and flexible load shape. Generally, these are the possible demand side management techniques that can be employed in future smart grids. These six demand side management techniques are illustrated below in Figure 1.2.

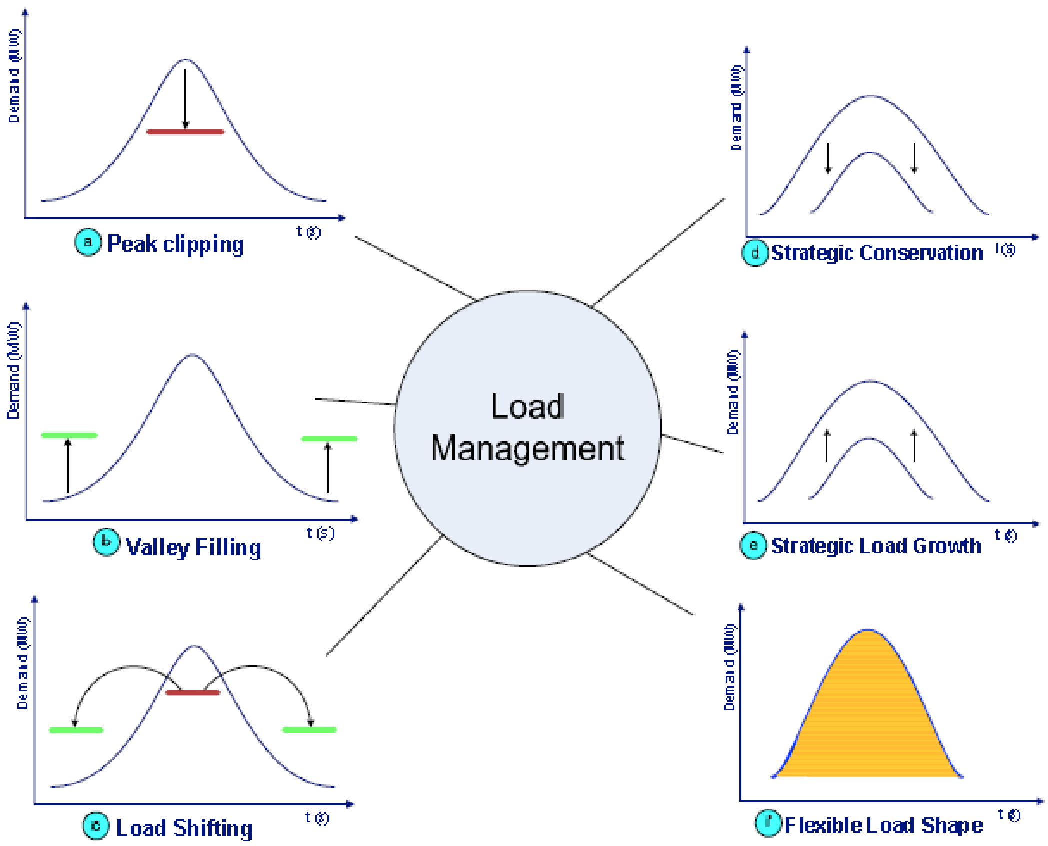


Figure 1.2 Demand Side Management techniques

DSM Techniques: -

- **Peak Clipping** - or the reduction of the system peak loads, embodies one of the classic forms of load management. Peak clipping is generally considered as the reduction of peak load by using direct load control. Direct load control is most commonly practiced by direct utility control of either service to customer facilities or of customers' appliances. While many utilities consider this as means to reduce peaking capacity or capacity purchases and consider control only during the most probable days of system peak, direct load control can be used to reduce operating cost and dependence on critical fuels by economic dispatch.

- **Valley Filling** - Is the second classic form of load management and applies to both gas and electric systems. Valley filling encompasses building off-peak loads. This may be particularly desirable where the long-run incremental cost is less than the average price of energy. Adding properly priced off-peak load under those circumstances decreases the average price. Valley filling can be accomplished in several ways, one of the most popular of which is new thermal energy storage (water heating and/or space heating) that displaces loads served by fossil fuels.

- **Load Shifting** - Is the last classic form of load management and also applies to both gas and electric systems. This involves shifting load from on-peak to off-peak periods. Popular applications include use of storage water heating, storage space heating, coolness storage, and customer load shifts. The load shift from storage devices involves displacing what would have been conventional appliances.

- **Strategic Conservation** - Is the load shape change that results from programs directed at end use consumption. Not normally considered load management, the change reflects a modification of the load shape involving a reduction in consumption as well as a change in the pattern of use. In employing energy conservation, the planner must consider what conservation actions would occur naturally and then evaluate the cost-effectiveness of possible intended programs to accelerate or stimulate those actions. Examples include weatherization and appliance efficiency improvement.

- **Strategic Load Growth** - Is the load shape change that refers to a general increase in sales beyond the valley filling described previously. Load growth may involve increased market share of loads that are or can be, served by competing fuels, as well as economic development.

Load growth may include electrification. Electrification is the term being employed to describe the new emerging electric technologies surrounding electric vehicles, industrial process heating, and automation. These have a potential for increasing the electric energy intensity of the industrial sector. This rise in intensity may be motivated by reduction in the use of fossil fuels and raw materials resulting in improved overall productivity.

- **Flexible Load Shape** - Is a concept related to electric system reliability, a planning constraint. Load shape can be flexible - if customers are presented with options as to the variations in quality of service that they are willing to allow in exchange for various incentives. The program involved can be variations of interruptible or curtail able load; concepts of pooled integrated energy management systems; or individual customer load control devices offering service constraints.

1.3 WHY LOAD SHIFTING TECHNIQUE?

Load shifting is widely applied as the most effective load management technique in current distribution networks. Load shifting takes advantage of time independence of loads, and shifts loads from peak time to off-peak time. Strategic conservation aims to achieve load shape optimization through application of demand reduction methods directly at customer premises. The distribution management system has to consider this for longer term implications of demand reduction on network

1.3.1 Customer Satisfaction

As other techniques of demand side management possess load shedding or, encourages consumers to reduce consumption. Whereas in this load shifting technique, existing load devices are brought into operation during low demand period, thus this brings consumers further satisfaction with reduced cost.

1.4 PROJECT OBJECTIVE

The proposed project is an alternative to traditional load shedding, fall in system frequency and overall cost effectiveness. These are discussed in detail below.

- Load Shedding - The proposed project is an alternative to traditional load Shedding
- Frequency Drop - Sudden fall of system frequency when demand on a power system is greater than the generation.
- Cost Effectiveness - Develop efficient utilization strategy for electricity, and encourages consumers to help flattening their load curve.

1.5 ORGANIZATION OF THESIS

Chapter 1 introduces the various aspects of Power System Network and explains the need for the Demand Side Management.

Chapter 2 presents the survey conducted for Demand Side Management, Dynamic Tariff and controllable loads and optimizing them using Genetic algorithm.

Chapter 3 deals the modelling of proposed DSM Methodology, with the problem formulation and objective load cure fixing on the system.

Chapter 4 presents the simulation work carried out for test system, using methods for simultaneous optimization using Genetic algorithm

Chapter 5 deals with the analysis of daily campus load consumption, list of controllable loads that can be shifted and flexibility factor.

Chapter 6 presents the list of results obtained for various case studies performed for load power sources and resources.

Chapter 7 presents the conclusion and future scope of the project.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, the various papers used as a reference and the ideologies behind the approach for the co-ordination and briefing. A summary of how Demand Side Management is implemented.

2.2 LITERATURE SURVEY FOR DEMAND SIDE MANAGEMENT

Nandkishor Kinhekar (2015) demonstrated a load shifting demand side management (DSM) technique used to shift AC industrial loads in response to time of day (TOD) tariff. An attempt was made to study the impact of DSM strategies with optimal shifting of AC devices in the presence of DC Bus. Hence a DSM strategy with DC bus in the presence of solar renewables and battery storage can substantially reduce average energy cost for demand to response and peak load burden on AC distribution utilities.

Thillainathan Logenthiran (2012) proposed a day-ahead load shifting technique, mathematically formulated as a minimization problem. A heuristic-based Evolutionary Algorithm (EA) that easily adapts heuristics in the problem was developed for solving this minimization problem. Henceforth the strategy achieves substantial savings, while reducing the peak load demand of the smart grid.

Fazeli.A (2011) discusses the benefits of transforming conventional power system into decentralized systems which are composed of clusters of smart energy communities, supplied mainly by renewable energy sources. The model is then utilized to quantify the potential benefits of applying load shifting demand side management with a variable severity level.

Govardhan. M (2014), uses two essential approaches of energy balance (i.e. energy shifting) and load reduction during peak hours. This ultimately results in energy saving and cost reduction of a system, comprising of 26 generating units for simulation study using gbest artificial bee colony algorithm. The test results confirm significant savings in cost and energy consumption while peak load demand is reduced.

Gupta. M (2014), insights a proto type AMI based Demand Side Management model for residential end user using smart metering for collection of data and implementation of peak load reduction strategies for home demand side management (DSM). The model comprises the grid connected system with photovoltaic and energy storage system for power backup. At the time of peak load curtailment from utility side, this module ensures the continuity of power supply to the end user.

Hamidi.V (2007), investigates the potential contribution to network security from greater demand side management and the requirement for additional control mechanism to achieve the full potential benefit and looks into the potential demand manipulation that can be achieved from existing control The benefits to the system security is quantified to a system with varying degree of intermittent generation.

Moradi.M.H (2008), compares two market-clearing procedures for CRM in terms of supply side management (SSM) only and economic efficiency of demand side management (DSM) to avoid transmission congestion in an optimum manner, and also proposes a zonal-based congestion relief management approach (ZCMA) to better relieve the congested lines in large systems. These zones are determined based on the lines active power from sensitivity index / the congestion relief index (CRI). He also uses the supply and demand side management (SSM & DSM) in the most sensitive zones

Thus with the literature survey done on Demand Side Management, it was clear that the goal of demand side management is to encourage the consumer to use less energy during peak hours, or to move the time of energy use to off-peak times such as night-time and weekends. Peak demand management does not necessarily decrease total energy consumption, but could be expected to reduce the need for investments in networks and/or power plants for meeting peak demands.

2.3 LITERATURE SURVEY FOR GENETIC ALGORITHM

Abessi.A (2015), describes the integration of these end-user reactive-power-capable devices is investigated to provide voltage support to the grid. Due to the limitation on the number of smart homes, at first, the effective locations for injecting the reactive power into the distribution system is determined (i.e., Q-C buses) and showed how reactive power resources connected at those buses can be controlled. For control purposes, centralized support distributed voltage control (CSDVC) algorithm is proposed and the distribution system is decomposed into different areas by using ε-decomposition.

Eunji Lee (2014) proposed an algorithm that dynamically changes the power mode of each electric device according to the change of electricity prices. He formulates the electricity usage scheduling problem as a real-time task scheduling problem, and shows that it is a complex search problem that has an exponential time complexity. The proposed scheme uses an efficient heuristic based on genetic algorithms to cut down the huge searching space and finds a reasonable schedule within a feasible time budget.

Hussain. S (2015) proposed a power flow control scheme using a framework of fuzzy logic (FL) and genetic algorithm (GA) to efficiently manage desired power flow levels within the smart grid. A fuzzy decision criterion is designed to choose a most suitable power source to deliver power to a certain demand. GA is used to choose a most suitable route from source to demand and optimize a cost function based on distance. Simulations show that the smart grid power flow can achieve the desired thresholds by incorporating the proposed approach even in the presence of unpredictable power fluctuations from renewable energy resources

Quan.H (2015), Insights the nonparametric neural network-based prediction intervals (PIs) are implemented for forecast uncertainty quantification. Instead of a single level PI, wind power forecast uncertainties are represented in a list of PIs. The Monte Carlo simulation method is used to generate scenarios from the ECDF. Then the wind power scenarios are incorporated into a stochastic security-constrained unit commitment (SCUC) model. The heuristic genetic algorithm is utilized to solve the stochastic SCUC problem.

Storti.G.L (2013), describes joint optimization of both topology and network parameters in order to minimize the total active power losses in a real Smart Grid. The grid has been accurately modelled and simulated in the phasor domain by Matlab/Simulink, relying on the SimPowerSystems ToolBox, following a Multi-Level Hierarchical and Modular approach. Network optimization is faced by defining and solving a suited multi-objective optimization problem, considering suited constraints on nominal operative ranges on voltages and currents, as well as on generator's capability functions, in order to take into account safety and quality of service issues. To this aim it is adopted a genetic algorithm, defining a suited fitness fun the nonparametric neural network-based prediction intervals (PIs) are implemented for forecast uncertainty quantification. Instead of a single level PI, wind power forecast uncertainties are represented in a list of PIs.

Tan Ma (2013), demonstrated a statistical forecasting model of the energy requirement of the PEVs network at different times during the day is developed based on statistical US drivers' driving habits. With historical solar irradiance, and wind speed in this area, genetic algorithm

(GA) is used to find the optimal scale of the renewable farm that can feed proper power for the PEVs network.

Vineeta (2012), proposed a multi layered approach to provide energy and spectrum efficient designs of Cognitive Radio networks at the smart grid utility, which is mainly motivated by the explosive data volume, diverse data traffic, and need for QoS support. The network architecture is decomposed into three subareas: cognitive home area network, cognitive neighbourhood area network, and cognitive wide area network, depending on the service ranges and potential applications.

Yue K.W (2011) insights distributed power grid and energy storage system connected to the grid two indicators to current power quality assessment indicators, making the object of evaluation more comprehensive and reasonable. Comprehensive assessment of power quality, making the assessment results more objective and accurate, constructed artificial neural network model of comprehensive assessment of power quality; take accelerated genetic algorithm to solve nonlinear optimization problem.

Thus with the literature survey done on genetic algorithm, it was clear that genetic algorithm is a method for solving both constrained and unconstrained optimization problems that is based on natural selection, the process that drives biological evolution. The genetic algorithm repeatedly modifies a population of individual solutions.

2.4 LITERATURE SURVEY FOR DYNAMIC PRICING

Abaza.A (2013), introduces an advanced and simple method to achieve demand side management (DSM)-based dynamic pricing (DP) technique. The proposed technique is executed through two phases. Firstly, demand sensitivity analysis is executed to define the sensitive/insensitive load centre at any load pattern of the system. Secondly, a set of equations is developed to determine the best required demand reduction at each load centre using particle swarm and heuristic optimization techniques.

Bu.S (2011), considered two types of electricity users, traditional electricity users who pay a fixed price and opportunistic electricity users who may change the electricity demand or even turn to another electricity retailer. Two game formulations are described for the proposed real-time pricing scheme. One formulation is proposed for a totally competitive environment. Another game formulation is proposed for a cooperative environment.

Du.H (2014), developed demand side coordinative energy management system for microgrid with demand response. The microgrid is grid-connected, including photovoltaic power generator (PV), energy storage device, and several industrial customers with adjustable load. an internal-dynamic-price-based renewable and demand side coordinative energy management model is proposed based on load and PV power forecasting results to maximize the profit of the renewable industrial park with a microgrid. The electricity demands of the rational customers interact mutually with the day-ahead internal dynamic prices.

Huq.M.Z (2010), analysed the opportunities to improve demand management in a home for peak load curtailment and implementing the dynamic pricing policy and also proposes the comprehensive assessment of different technologies available for home area network and develop an approach for selecting suitable technologies, which contribute to demand management

Misra.S (2013), presents a Markov Decision Process (MDP)-based scheduling mechanism for residential energy management (REM) in grid network. In this mechanism, the Home Energy Management Unit (HEMU) acts as one of the players, the Central Energy Management Unit (CEMU) acts as another player. The HEMU interacts with the CEMU to fulfil its energy request within its desired budget. The CEMU follows its own dynamic pricing mechanism to decide the price per unit energy for on-peak and off-peak hours.

Philippou.N (2015), proposed a new tool for the optimization of dynamic tariffs is developed. This is based on statistical analysis of the consumption profiles and optimization procedures, aiming to derive the most appropriate Time-of-Use (ToU) tariffs. The developed DSM ToU blocks in comparison with the load curve exhibit a mean absolute percentage error and root mean square error.Thus with the literature survey done on Dynamic Pricing, it was clear that dynamic pricing is a strategy where the provider of a service or supplier of a commodity, may vary the price depending on the time-of-day when the service is provided or the commodity is delivered. The rational background of time-based pricing is expected or observed change of the supply and demand balance during time.

Thus with the literature survey done on Dynamic Pricing, it was clear that dynamic pricing is a strategy where the provider of a service or supplier of a commodity, may vary the price depending on the time-of-day when the service is provided or the commodity is delivered. The rational background of time-based pricing is expected or observed change of the supply and demand balance during time.

2.5 LITERATURE SURVEY FOR CONTROLLABLE LOADS

Goya.T (2011), discusses on the reactive power schedule of the controllable loads, and determines the optimal operation of the thermal units satisfied the voltage constraint. Simulation results show the validation of the proposed method and validate the performance and effectiveness of the algorithm for controllable loads and batteries.

Klein.S.A (2008), describes an alternative means of accommodating the variability of wind power production. Current approaches all focus on either real-time adjustment of other generation, curtailing wind power production, storing excess wind generation in pumped hydro or similar storage facilities, or by on/off curtailment of loads. Except for on/off curtailment the load variability is accepted and the generation adjusted in real-time to balance generation and load in the grid and maintain frequency regulation.

Niska.H (2013), presents a data-driven approach, for recognising and modelling of controllable heating loads of small customers. Main computational methods used include self-organizing map (SOM), k-means algorithm and support vector regression (SVR). The approach consists of two major stages, namely (i) the recognition of customers that have electrical heating using clustering based on extracted behavioural features and (ii) the predictive regression modelling of controllable heating loads in recognised customer segment. One year of hourly metered electricity consumption data from 525 customers having heterogeneous heating systems, combined with available hourly measured outdoor temperatures and site-specific building information, were used as the base data in the model development and validation.

Sharma.I (2015), presents a new modelling framework for analysis of impact and scheduling of price-responsive as well as controllable loads in a three-phase unbalanced distribution system. The price-responsive loads are assumed to be linearly or exponentially dependent on price, i.e., demand reduces as price increases and vice versa. The effect of such uncontrolled price-responsive loads on the distribution feeder is studied as customers seek to reduce their energy cost. Secondly, a novel constant energy load model, which is controllable by the local distribution company (LDC), is proposed in this paper.

Tokudome.M (2009), presented a methodology for grid frequency and voltage control by distributed controllable loads. The power system consists of diesel generators, wind generators, photovoltaics and loads. By applying power consumption control under droop characteristics, grid frequency and terminal voltage fluctuations are maintained around rated value. In order to verify the effectiveness of the proposed system.

Thus with the literature survey done on Controllable loads, it was clear that is the process of balancing the supply of electricity on the network with the electrical load by adjusting or controlling the load rather than the power station output. This can be achieved by direct intervention of the utility in real time, by the use of frequency sensitive relays triggering the circuit breakers (ripple control), by time clocks, or by using special tariffs to influence consumer behaviour.

2.6. CONCLUSION

Thus this chapter has dealt with the literature review in the areas of DSM, Dynamic Pricing, Controllable loads and Genetic Algorithm which has helped to combine all the principles and optimize it efficiently.

CHAPTER 3

DEMAND SIDE MANAGEMENT MODELLING

3.1 DSM METHODOLOGY

A load scheduling Demand Side Management strategy is proposed to shift all controllable AC loads of campus at different hours of the day while DC loads continued to receive power so as to reduce peak demand of the overall distribution system. It uses load shifting as the primary technique that can be utilized by the central controller. Objective of the demand side management could be maximizing the use of renewable energy resources, maximizing the economic benefit, minimizing the power imported from the main distribution grid, or reducing the peak load demand. The proposed optimization algorithm aims to bring the final load curve as close to the objective load curve as possible such that the desired objective of the Demand Side Management strategy is achieved. For example, if the objective of the demand side management is to reduce the utility bill, an objective load curve will be chosen such that it is inversely proportional to electricity market prices. Indian power system is in developing state where there is an energy deficit in peak power served. Hence industrial AC loads are considered for scheduling as per TOD tariff so that consumption of power will be reduced during peak load period. It is an energy scheduling approach based on fixed TOD tariff. This fixed TOD tariff is issued by the State Electricity Regulatory Commissions having discussion with the distribution utilities. These are declared to customers in advance by the utility so that they can extract its benefits by running their loads to low TOD tariff as shown in Figure 3.1. Most of the industrial AC loads of the system under study are running in shifts. It is quite possible to schedule the loads during low energy cost period. Hence, the aim of the proposed optimization technique is to bring the final load curve as close as possible to the pre-defined target load curve of the system. The target load curve is defined as inversely proportional to the TOD tariff. According to the proposed architecture, the demand side management system receives the objective load curve as an input, and calculates the required load control actions in order to fulfil the desired load consumption. Therefore, the proposed algorithm is flexible in that it is completely independent from the criteria used to generate the objective load curve as shown in Figure 3.2. The demand side management is carried out at the beginning of a predefined control period which is typically a day. Then, the control actions are executed in real-time based on the results.

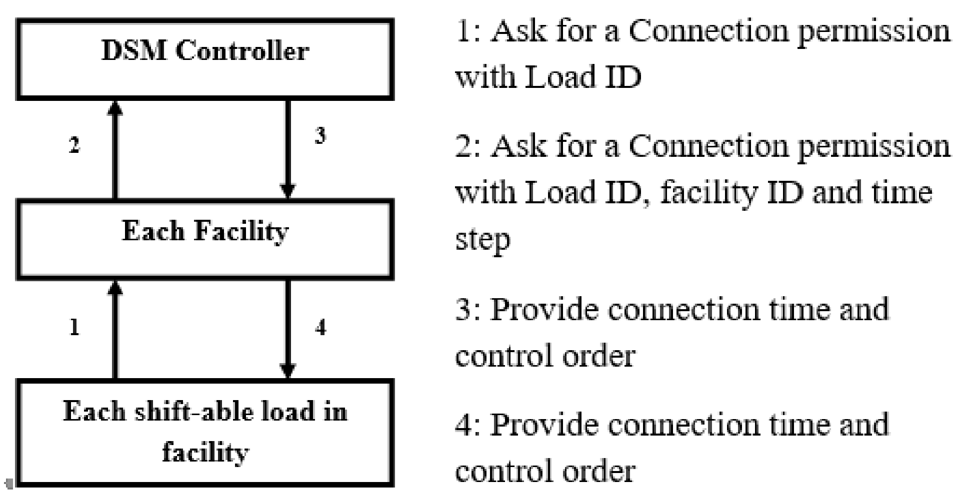


Figure 3.1 DSM Architecture

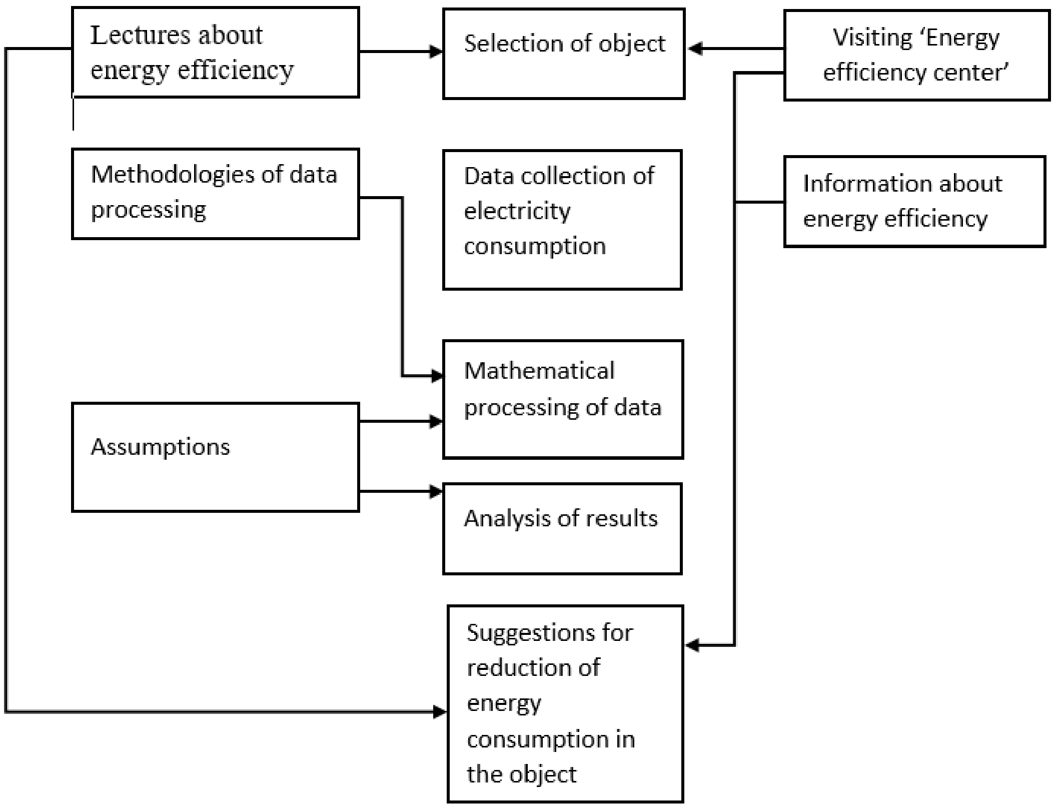


Figure 3.2 DSM Methodology

3.2 PROBLEM FORMULATION

The proposed demand side management strategy schedules the connection moments of each shiftable device in the system in a way that brings the load consumption curve as close as to the objective load consumption curve. Proposed load shifting technique is mathematically formulated treating Equation 3.1 as the objective function.

$$Minimize \sum_{t=1}^{N} (ACP_{ac}\,(t) - Objective(t))^2 \tag{3.1}$$

Where Objective(t) is the value of the objective curve at time t, and ACPac(t) is the actual power consumption at time t.

3.2.1 Actual Power Consumption

The actual power consumption at any instant is computed with respect to the forecasted load and shiftable loads at the time interval t. This is taken as the total consumption for the time interval.

$$ACP_{ac}(t) = \textit{Forecast(t)} + \textit{Connect(t)} + \textit{Disconnect(t)} \tag{3.2}$$

Where Forecast(t) is the forecasted consumption at time t, and Connect(t) and Disconnect(t) are the amount of loads connected and disconnected at time t respectively during the load shifting process.

3.2.2 Objective Function

Objective of the demand side management could be maximizing the use of renewable energy resources, maximizing the economic benefit, minimizing the power imported from the main distribution grid, or reducing the peak load demand. An objective load curve will be chosen such that it is inversely proportional to electricity market prices.

The mathematically formulated objective function is given below,

$$Objective(t) = \frac{C_m}{C_{max}} \times \frac{1}{C(t)} \times \sum_{s=1}^{N=48} P_{fixa}(s) \tag{3.3}$$

where C_m is the average of the prices during the period, C_{max} is the maximum price of the period and $C(t)$ is the price at the time interval t.

3.2.2 Forecasted Load

Electricity as a product has very different characteristics compared to a material product. For instance, electricity energy cannot be stored as it should be generated as soon as it is demanded. Any commercial electric power company has several strategic objectives. One of these objectives is to provide end users (market demands) with safe and stable electricity. Therefore, Electric Power Load Forecasting (EPLF) is a vital process in the planning of electricity industry and the operation of electric power systems. Accurate forecasts lead to substantial savings in operating and maintenance costs, increased reliability of power supply and delivery system, and correct decisions for future development. Electricity demand is assessed by accumulating the consumption periodically; it is almost considered for hourly, daily, weekly, monthly, and yearly periods. Here, in this project a 2-day consumption load curve is recorded, averaged and considered as the forecasted load.

3.2.3 Load shifting process

Connect(t) is made up of two parts: the increment in the load at time t due to the connection times of devices shifted to time t, and the increment in the load at time t due to the device connections scheduled for times that precede t as shown in Figure 3.3.

$$Connect(t) = \sum_{i=1}^{N} \sum_{k=1}^{D} Y_{kit} \times P_{1k} + \sum_{l=1}^{j-1} \sum_{i=1}^{t-1} \sum_{k=1}^{D} Y_{ki(t-1)} \times P_{(1+l)k} \times \Delta t$$

(3.4)

Where Y_{kit} is the number of devices of type that are shifted from time step i to t,D is the number of device types, P_{1k} and $P_{(1+l)k}$ are the power consumptions at time steps 1 and (1+l).

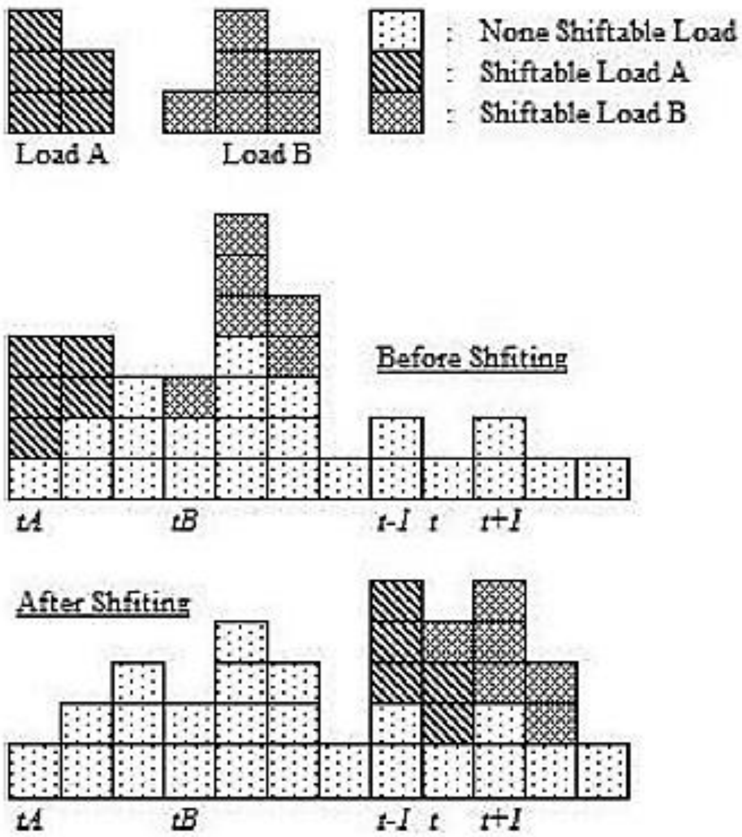


Figure 3.3 Connect

Disconnect () consists of two parts: the decrement in the load due to delay in connection times of devices that were originally supposed to begin their consumption at time step t, and the decrement in the load due to delay in connection times of devices that were expected to start their consumption at time steps that precede t as shown in Figure3.4.

$$Disconnect(t) = \sum_{q=t+1}^{t+m} \sum_{k=1}^{D} Y_{\underset{t}{kq}} \times P_{1k} + \sum_{l=1}^{j-1} \sum_{q=t+1}^{t+m} \sum_{k=1}^{D} Y_{kq(t-1)} \times P_{(1+l)k} \times \Delta t \tag{3.5}$$

Where Y_{ktq} is the number of devices of type that are delayed from time step t to q , m is the maximum allowable delay.

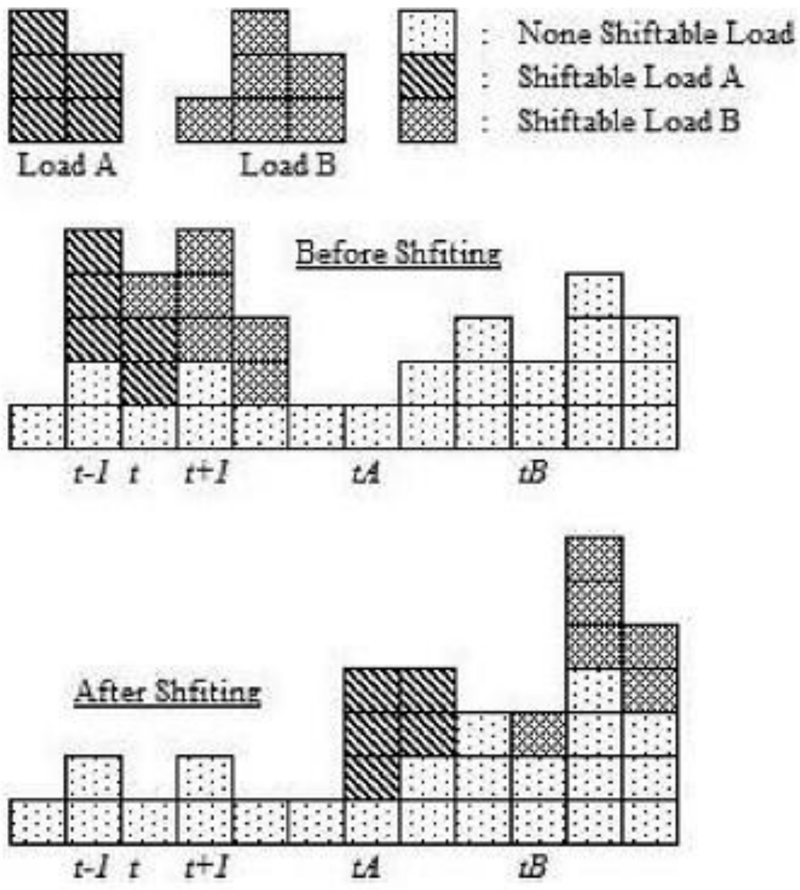


Figure 3.4 Disconnect

3.2.4 Power Balance Equation

The number of devices shifted cannot be a negative value.

$$Y_{kit} > 0 \qquad \forall \; i, j, k \tag{3.6}$$

The total number of controllable devices at a particular time step must be less than or equal to the total number of available devices at that time step. A constraint related to this can be formulated as: -

$$\sum_{t=1}^{N} Y_{kit} \leq Ctrlable(i) \tag{3.7}$$

Where Ctrlable(i) is the number of devices of type k available for control at time step i.

A device can only be connected forward not backward, which can be expressed as,

$$Y_{kit,ac}=0 \qquad \forall \; i, j, k \tag{3.8}$$

A constraint is imposed on the maximum permissible time delay for all devices according to the agreement between utility and consumer to limit the available number of time steps to be shifted, which can be given as

$$Y_{kit,ac}=0 \qquad \forall \; (t\text{-}i)>m. \tag{3.9}$$

The power balancing equation for entire distribution system is given as,

$$P_{L,dc}(t) + P_{L,ac}(t) + \sum_{i=1}^{btnum} P_{bt,i,t}^{c} + P_{\left(\frac{ac}{dc}\right)Loss}(t)$$

$$= \sum_{i=1}^{btnum} P_{bt,i,t}^{d} - P_{\left(\frac{dc}{ac}\right)Loss}(t) \quad + P_{G,ac}(t) \qquad (3.10)$$

3.3 OBJECTIVE LOAD CURVE FIXING

The objective function taken into consideration consists in minimize the energy costs of the customers of this smart grid. For this, an objective curve can be modelled inversely proportional to the energy prices. But due to flat tariff structure in the campus, tracking the dynamic price of electricity is difficult in this scenario. Hence the total time steps are divided into four phases. The loads are then averaged for the respective phases.

Fixing the target load by dynamic pricing is given by the equation,

$$Objective(t) = \frac{price_{avg}}{price_{max}} \times \frac{1}{price(t)} \times \sum_{i=1}^{24} Pload(i) \qquad (3.11)$$

3.4 DEVICE PARAMETERS & STRUCTURE

Each and every device data stored in separate memory connected to microprocessor. Those data can be retrieved at any time and it implies the device details like device type, starting time, operation time, etc., This data tells about the information, when to switch on/off the particular device during real time load shifting as shown in Table 3.1.

Table 3.1 DSM protocol structure

Device Name
Device Number
Device Rating
Initial Scheduling Time
Operation Time
Operation period
Maximum permissible delay
Original Delay

3.5 CONSTRAINS

In defining this model, we combine the several constraints and objectives proposed in the literature in papers on DSM frameworks. In order to give a coherent and uniform description of the model, we make some simplifying assumptions in harmonizing the different works to which we refer. Note that the model that we describe in this section is defined for individual users and in reference to the day-ahead scenario. However, it can be easily extended to consider collaborative users and real-time conditions. In order to make the optimization model easier to follow and understand, we group its constraints into three categories, as represented in Figure 3.5

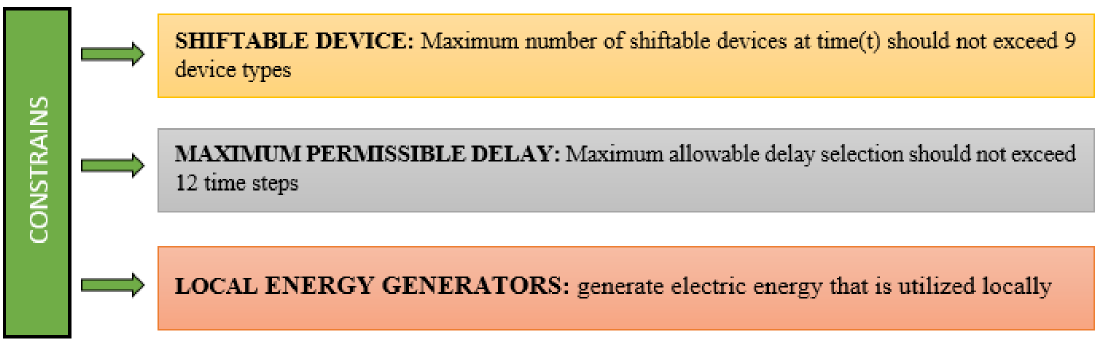


Figure 3.5 General constrains

3.5.1 Delay parameter selection

The varying parameter in DSM protocol is Delay. The loads can never be advanced, but can be delayed. The maximum permissible delay table is set up for the college. The loads are not that much flexible. Hence delay factor or flexibility factor is less. Even controllable ac devices also found in lesser number. Pseudo code for choosing maximum delay: -

```
if (Total time steps – Starting time step – Operation period > Maximum delay)
then Maximum delay remains same;
else
Maximum delay = (Total time steps – Starting time step – Operation period;
end
```

3.6 SUMMARY

Thus this chapter has dealt with the modelling of DSM, for a generic environment. The actual load function as given in Equation 3.2, is compared with a target load function as given in equation 3.3, whose difference is considered as an error. The minimization of this error as indicated in Equation 3.1, is done, which leads to significant reduction of peak load. This is carried out by shifting of loads to off peak periods. Thus, this approach is further applied and studied for a campus infrastructure with the integration of existing assets such as diesel generators and photo voltaic panels.

CHAPTER 4

DEMAND SIDE MANAGEMENT IMPLEMENTATION

4.1 INTRODUCTION

As in the previous chapter, a DSM model has been built, and the implementation of this model to a test system will be discussed here. The test system considered for simulation is from Mumbai, the capital city of Maharashtra state in India. As this test system has already been studied and analysed applying DSM strategy whose results are discussed by Nandkishor Kinhekar [17], is considered here for simulation. Moreover, the model built is heuristically optimized based on Evolutionary Algorithm (EA). In this case, Genetic Algorithm being a commonly used for optimization is considered which is also discussed here in this chapter.

4.1 GENETIC ALGORITHM

The genetic algorithm is a method for solving both constrained and unconstrained optimization problems that is based on natural selection, the process that drives biological evolution. Genetic algorithms are a very effective way of quickly finding a reasonable solution to a complex problem. Granted they aren't instantaneous, or even close, but they do an excellent job of searching through a large and complex search space. Genetic algorithms are most effective in a search space for which little is known. You may know exactly what you want a solution to do but have no idea how you want it to go about doing it. This is where genetic algorithms thrive. They produce solutions that solve the problem in ways you may ever have even considered. Then again, they can also produce solutions that only work within the test environment and flounder once you try to use them in the real world. It thrives in an environment in which there is a very large set of candidate solutions and in which the search space is uneven and has many hills and valleys. True, genetic algorithms will do well in any environment, but they will be greatly outclassed by more situation specific algorithms in the simpler search spaces.

4.1.1 Process Flow

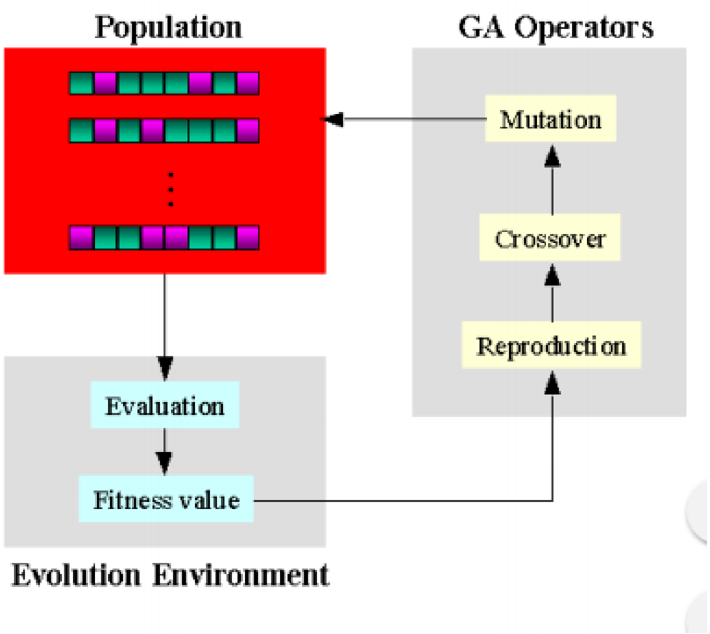


Figure 4.1 Genetic Algorithm Evolution Flow

Algorithm

STEP 1. Determine the number of chromosomes, generation, and mutation rate and crossover rate value

STEP 2. Generate chromosome-chromosome number of the population, and the initialization value of the genes chromosome-chromosome with a random value

STEP 3. Process steps 4-7 until the number of generations is met

STEP 4. Evaluation of fitness value of chromosomes by calculating objective function

STEP 5. Chromosomes selection

STEP 6. Mutation and Crossover

STEP 7. New Chromosomes (Offspring)

STEP 8. Solution (Best Chromosomes)

4.1.2 GA Parameters

1. Number of Chromosomes:

Less population number limits the search space. Hence, population number must be higher.

2. Number of generation:

When the chromosome length increases, then the occurrence of the optimal solution is also delayed. Hence, 'number of generations' setting must be high.

3. Cross over rate:

Crossover does not always occur, however. Sometimes, based on a set probability, no crossover occurs and the parents are copied directly to the new population. The probability of crossover occurring is usually 60% to 90%.

4. Mutation Rate:

The probability of mutation is usually between 1 and 2 tenths of a percent.

The optimization of the DSM model built is solved using genetic algorithm, and values shown in Table 4.1 are passed on during the program runtime to obtain the optimized solution. These values are arrived from a reference paper [21].

Table 4.1 GA Parameter Setting

Parameters	**Settings**
Number of chromosomes	50
Number of generations	800
Cross-over rate	0.9
Mutation rate	0.04

4.1.3 Selection Process

Roulette wheel selection

The higher the value of fitness the higher the chance for the chromosome to be selected. The basic part of the selection process is to stochastically select from one generation to create the basis of the next generation. The requirement is that the fittest individuals have a greater chance of survival than weaker ones. This replicates nature in that fitter individuals will tend to have a better probability of survival and will go forward to form the mating pool for the next generation. Weaker individuals are not without a chance. In nature such individuals may have genetic coding that may prove useful to future generations.

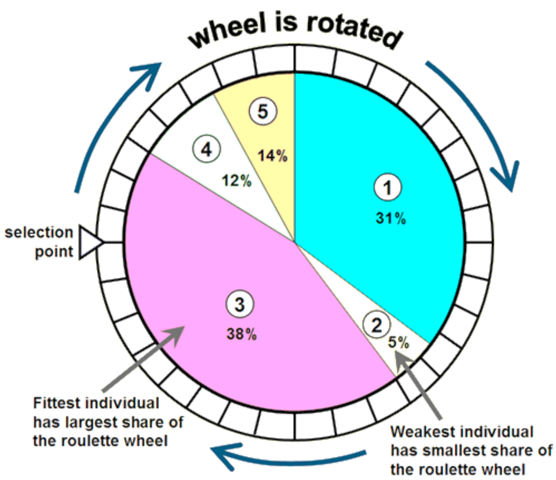


Figure 4.2 Roulette wheel selection process

4.1.4 Fitness Calculation

Fitness function is calculated by

$$Fitness = \frac{1}{1+\sum_{t=1}^{24}(PLoad(t)-Objective(t))^2} \quad (4.1)$$

4.1.5 Cross Over

Uniform crossover - bits are randomly copied from the first or from the second parent

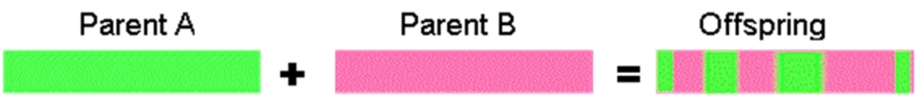


Figure 4.3 Uniform Crossover

11001011 + 11011101 = 11011111

Arithmetic crossover - some arithmetic operation is performed to make a new offspring

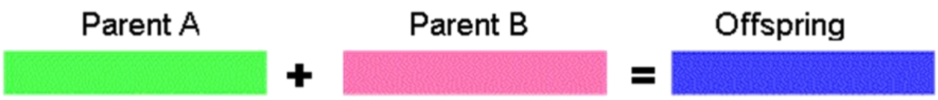


Figure 4.4 Arithmetic Crossover

- Most commonly used
- Parents: (x1,…,xn) and (y1,…,yn)
- Child $_1$ is: a.x + (1-a).y

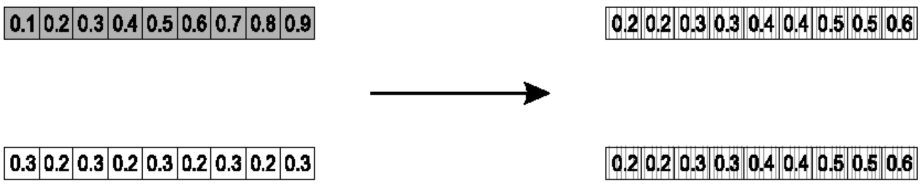


Figure 4.5 Arithmetic Crossover process

4.1.6 Mutation

Mutation is a genetic operator used to maintain genetic diversity from one generation of a population of genetic algorithm chromosomes to the next. It is analogous to biological mutation. Mutation alters one or more gene values in a chromosome from its initial state. In mutation, the solution may change entirely from the previous solution. Hence GA can come to better solution by using mutation. Mutation occurs during evolution according to a user-definable mutation probability. This probability should be set low. If it is set too high, the search will turn into a primitive random search

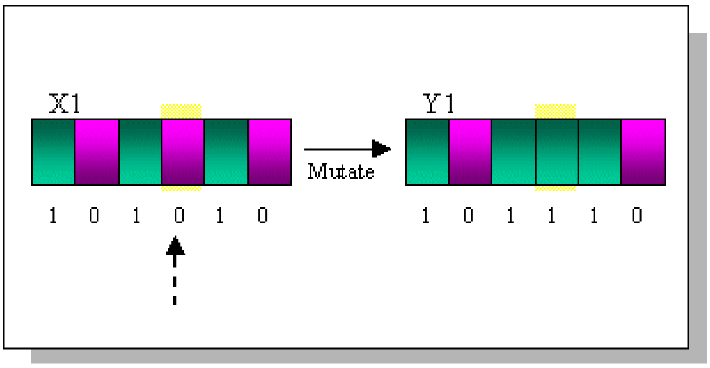


Figure 4.6 Mutation process

4.2 TEST SYSTEM

The usefulness of the proposed technique is illustrated by carrying out simulations on a practical distribution system containing industrial loads of utility in western region of India. The system considered for simulation is from Mumbai, the capital city of Maharashtra state in India. The approximate population and spread over area of the city is 12.5 million and 437.5 km^2, respectively. As this test system has already been studied and analysed applying DSM strategy whose results are discussed by Nandkishor Kinhekar [17], is considered here for simulation. The whole system has a residential customer base of approximately 0.35 million and 50 000 high tension (HT) and low tension (LT) and commercial and industrial customers in Mumbai city. The proposed load shifting technique was applied to a modified 15-bus, 11-kV practical ring distribution system for industrial loads only. System consists of 4 main feeders, 8 distribution lines, and 20 distribution transformers. The industrial loads are placed at bus number 10 to 15. The loads for assumed DC microgrid are placed at bus number 13, 14, and 15. The modified distribution network diagram for the practical system is shown in Figure 4.7. The measured hourly AC load consumption data of industrial customers for a day (24 hours) recorded by Automatic Meter Reading (AMR) system has been used as forecasted AC load for simulation. Dynamic pricing has been taken to generate the target AC load consumption curve. DC microgrid is likely to come up in India. Hence, to do the analysis on DC microgrid, a load survey was carried out for a group of industrial

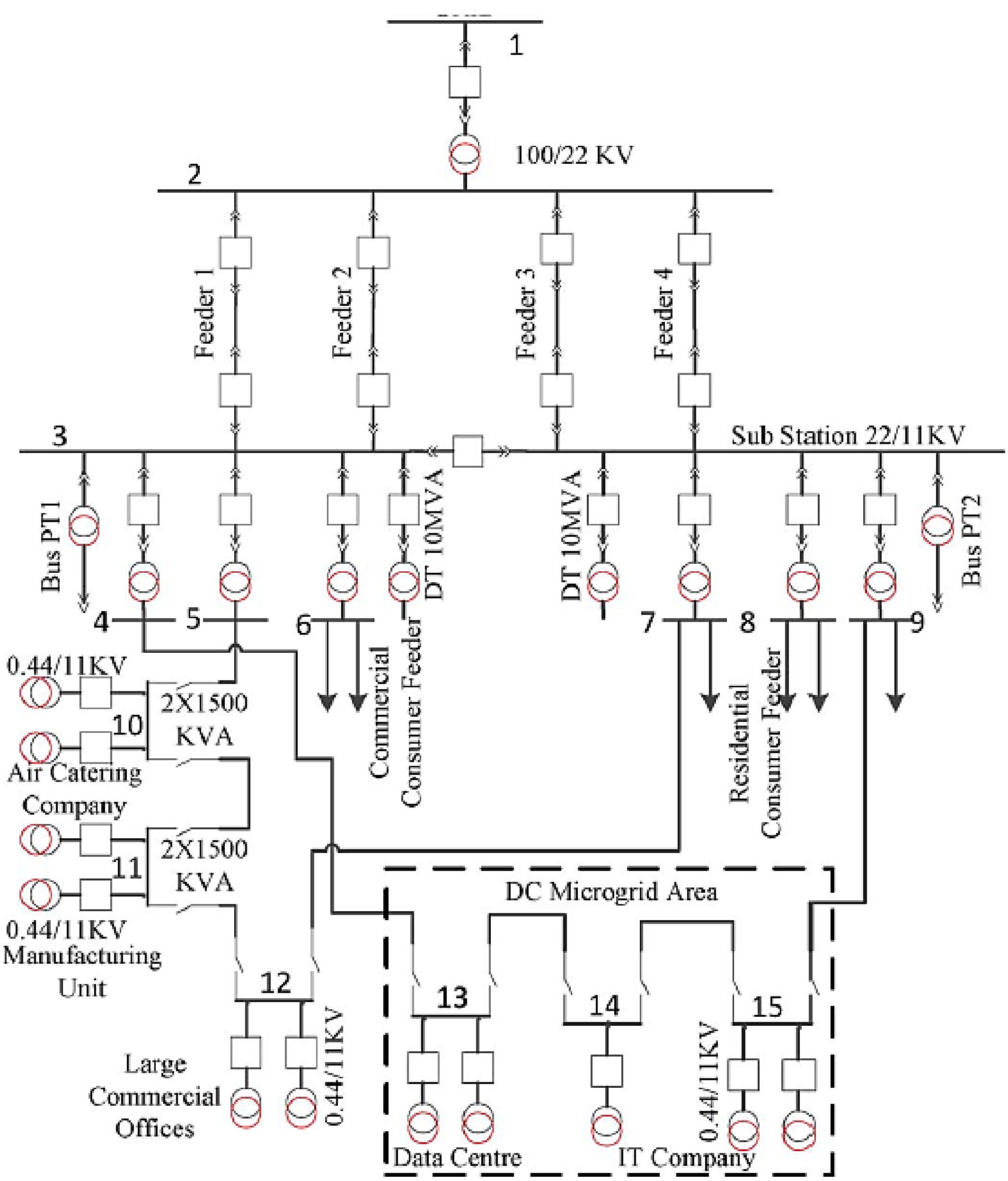


Figure 4.7 Practical distribution system network diagram

customers to know the percentage of DC loads available with customers. Different types of customers namely; air catering company, IT company, data centre, large commercial offices, and manufacturing unit are under the industrial category. Major loads in data centre and IT company such as servers, telecommunications equipment, computers, routers, data storage devices etc. are identified as DC loads. Hence, 50% of data centre and IT company load data supplied by the distribution utility is considered as DC load for simulation purpose. DC microgrid is assumed to be a small integrated part within whole AC distribution system. DC loads present in DC microgrid are assumed to be supplied only by DC sources like PV arrays and BSS. Power generation using fuel cell is not commercially accepted in India and hence it is not considered for the analysis. When there is insufficient solar, the power is taken from AC bus and BSS. Total 10 numbers of BSSs of 100 kWh each are used for simulation. Charging and discharging efficiency of a BSS is considered to be 90%. It is assumed that a BSS is charging from DC sources when ample generation is available or from the grid during off peak hours when TOD tariff is less. Discharging of BSS takes place through both DC microgrid and AC distribution system during emergency. Loss factor of 10% is considered for the losses taking place during DC to AC conversion while supplying power to AC distribution system. Power taken from DC renewable sources is costlier than that of AC pool prices. Also the power drawn from BSS is costlier than that drawn from DC renewable as it involves one-time battery installation cost and time to time maintenance cost. It is assumed that sufficient sunlight is available for 10 h from 7 a.m. in the morning to 5 p.m. in the evening during day time. Hence, PV array is the DC source available to feed DC loads during day time. DC renewable prices during day time are considered to be Rs. 6.5/kWh for 10 h and Rs. 9.5/kWh for rest of the hours, as BSSs are assumed to be main source of power supply during night time. Though the power supplied by DC renewable is costlier, it is mandatory to purchase power from renewable generations under the green power obligations, renewable purchase obligations led down by the Maharashtra Electricity Regulatory Commission (MERC), India. The maximum load demand of industrial customers, commercial customers and residential customers for whole grid in this study are 2727.3 kW, 1818.2 kW and 1363.3 kW respectively. On a typical day, the control period is started from 8 a.m. of present day to 8 a.m. of next day as peak is generally started around 8th hour of the day for a given distribution area. The consumption patterns of the AC devices under control for the customers are shown in Table 4.2.

Table 4.2 Hourly Forecasted Load

Time	**Price**	**Hourly Forecasted Load (kW)**		
		Residential	**Commercial**	**Industrial**
08:00 – 09:00	12.00	729.4	923.5	2045.5
09:00 – 10:00	9.19	713.5	1154.4	2435.1
10:00 – 11:00	12.27	713.5	1443.0	2629.9
11:00 – 12:00	20.69	808.7	1558.4	2727.3
12:00 – 13:00	26.82	824.5	1673.9	2435.1
14:00 – 15:00	13.81	745.2	1673.9	2678.6
15:00 – 16:00	17.31	681.8	1587.3	2629.9
16:00 – 17:00	16.42	667	1558.4	2532.5
17:00 – 18:00	9.83	951.4	1673.9	2094.2
18:00 – 19:00	8.63	1220.9	1818.2	1704.5
19:00 – 20:00	8.87	1331.9	1500.7	1509.7
20:00 – 21:00	8.35	1363.6	1298.7	1363.6
22:00 – 23:00	16.19	1046.5	923.5	1120.1
23:00 – 00:00	8.87	761.1	577.2	1022.7

Time	Price	Hourly Forecasted Load (kW)		
		Residential	Commercial	Industrial
00:00 – 01:00	8.65	475.7	404.0	974
01:00 – 02:00	8.11	412.3	375.2	876.6
02:00 – 03:00	8.25	364.7	375.2	827.9
03:00 – 04:00	8.10	348.8	404.0	730.5
04:00 – 05:00	8.14	269.6	432.9	730.5
05:00 – 06:00	8.13	269.6	432.9	779.2
06:00 – 07:00	8.34	412.3	432.9	1120.1
07:00 – 08:00	9.35	539.1	663.8	1509.7

Each area of the smart grid has different types of controllable devices, the details of which are given as follows.

A. Residential Area

The devices subjected to control in the residential area have small power consumption ratings and short durations of operation. Table 4.3 shows device types that are subjected to load control and their consumption patterns. There are over 2600 controllable devices available in this area from 14 different types of devices.

Table 4.3 Hourly Consumption of Device

Device Type	Hourly Consumption of Device (kW)			Number of Devices
	1st Hr	2nd Hr	3rd Hr	
Dryer	1.2	-	-	189
Dish Washer	0.7	-	-	288
Washing Machine	0.5	0.4	-	268
Oven	1.3	-	-	279
Iron	1.0	-	-	340
Vacuum Cleaner	0.4	-	-	158
Fan	0.20	0.20	0.20	288
Kettle	2.0	-	-	406
Toaster	0.9	-	-	48
Rice-Cooker	0.85	-	-	59
Hair Dryer	1.5	-	-	58
Blender	0.3	-	-	66
Frying Pan	1.1	-	-	101
Coffee Maker	0.8	-	-	56
Total	-	-	-	2604

The load pattern has been analysed with and without using DSM, is shown in the Figure 4.8. The target load curve shown in this figure is computed with reference to Equation 3.3 in Chapter 3. It can be seen that the peak loads have been shifted to off peak periods with the implementation of DSM. The utility bill of the residential area reduces from Rs.2,30,300 to Rs.2,23,420 with demand side management strategy, resulting in about 2.93% reduction in the operating cost

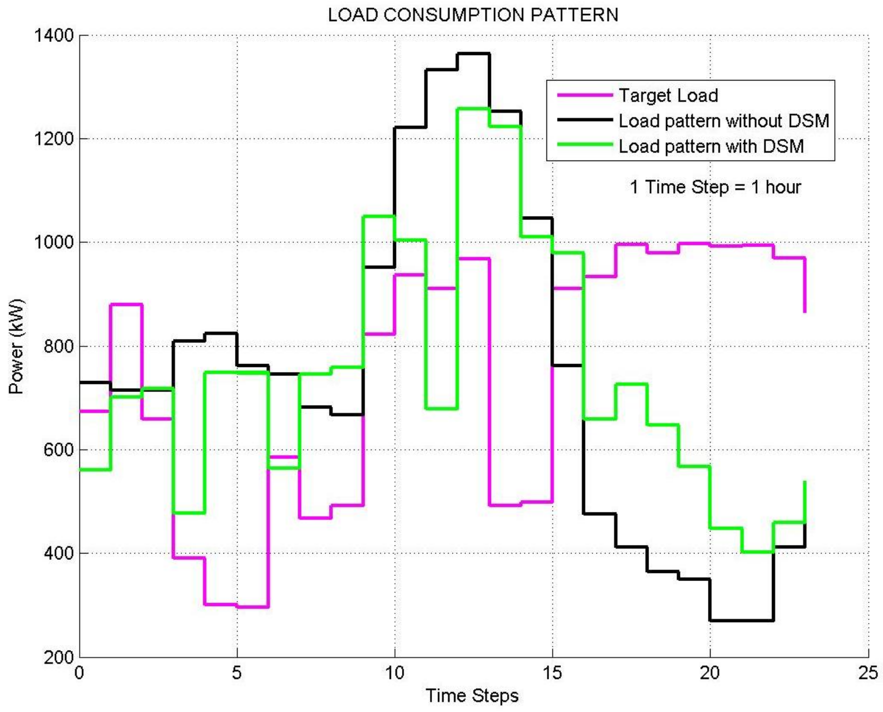


Figure 4.8 Load consumption pattern

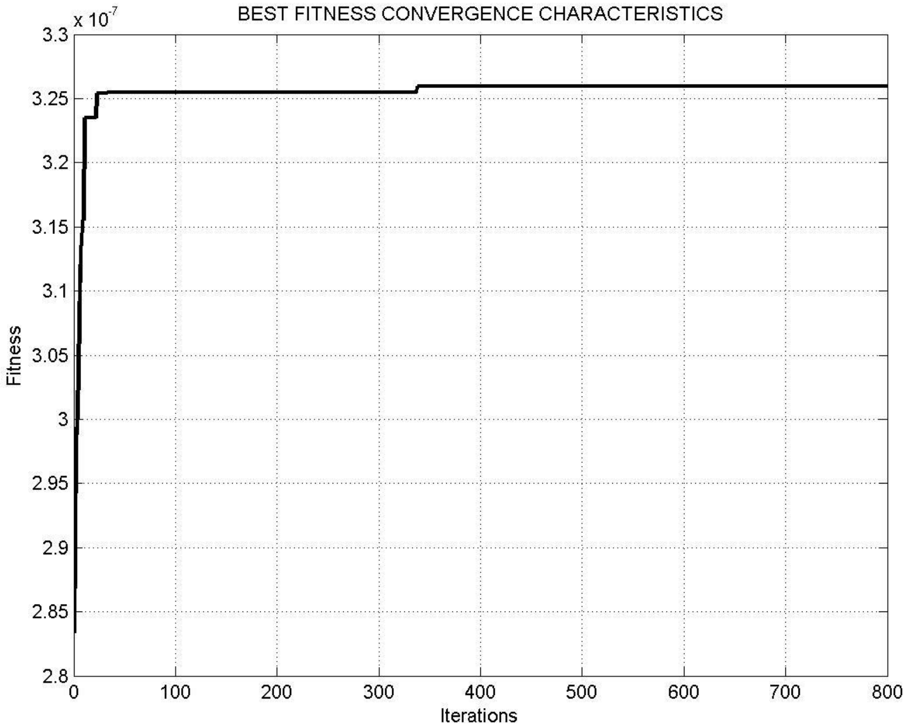


Figure 4.9 Best fitness convergence characteristics

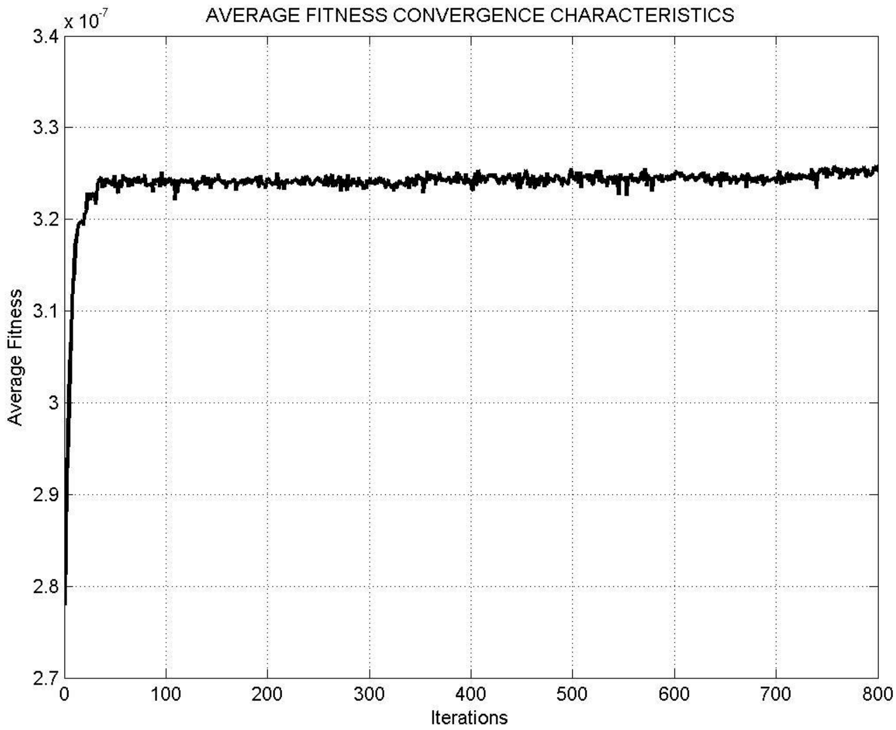


Figure 4.9 Average fitness convergence characteristics

B. Commercial Area

The devices subjected to load control in the commercial area have consumption ratings which are slightly higher than those in the residential area. The consumption patterns of the loads under the control are given in Table III. There are over 800 controllable devices available for control in this area from 8 different types of devices. The utility bill of the commercial area reduces from Rs.3,62,660 to Rs.3,47,600 with demand side management strategy, resulting in about 4.15% reduction in the operating cost.

Table 4.4 Hourly consumption of commercial devices

Device Type	Hourly Consumption of Device (kW)			Number Devices
	1st Hr	2nd Hr	3rd Hr	
Water Dispenser	2.5	-	-	156
Dryer	3.5	-	-	117
Kettle	3.0	2.5	-	123
Oven	5.0	-	-	77
Coffee Maker	2.0	2.0	-	99
Fan/AC	3.5	3.0	-	93
Air Conditioner	4.0	3.5	3.0	56
Lights	2.0	1.75	1.5	87
Total	-	-	-	808

The load pattern has been analysed with and without using DSM, is shown in the Figure 4.10. The target load curve shown in this figure is computed with reference to Equation 3.3 in Chapter 3. It can be seen that the peak loads have been shifted to off peak periods with the implementation of DSM.

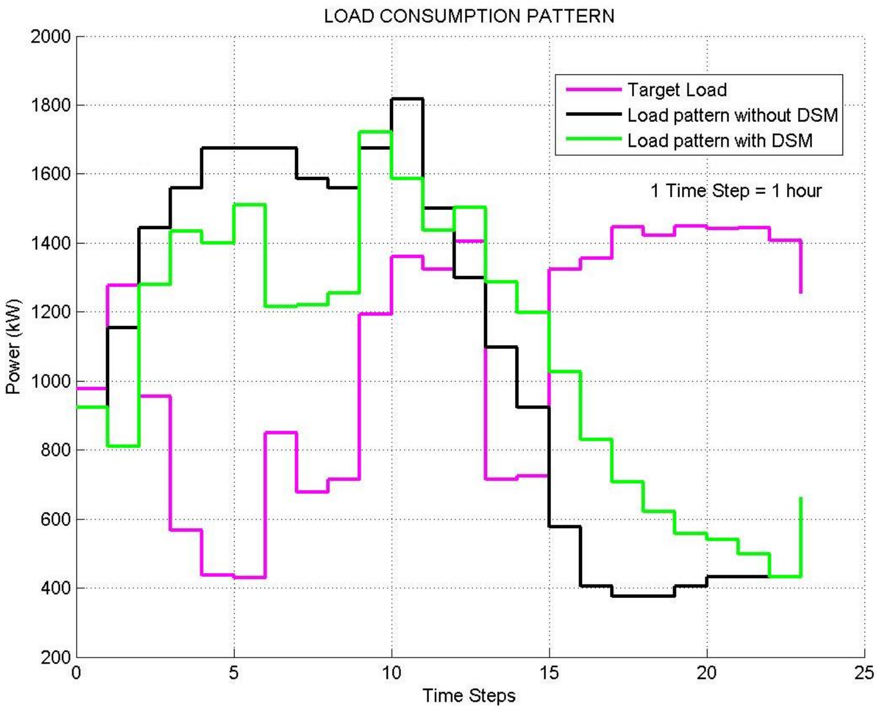


Figure 4.10 Commercial load consumption pattern

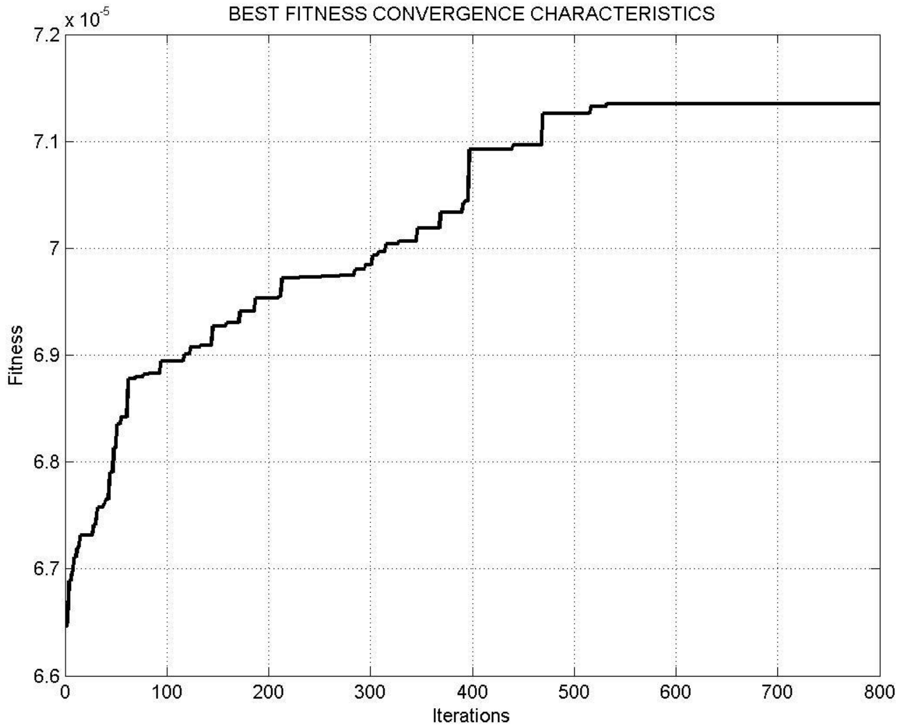


Figure 4.11 Commercial best fitness convergence characteristics

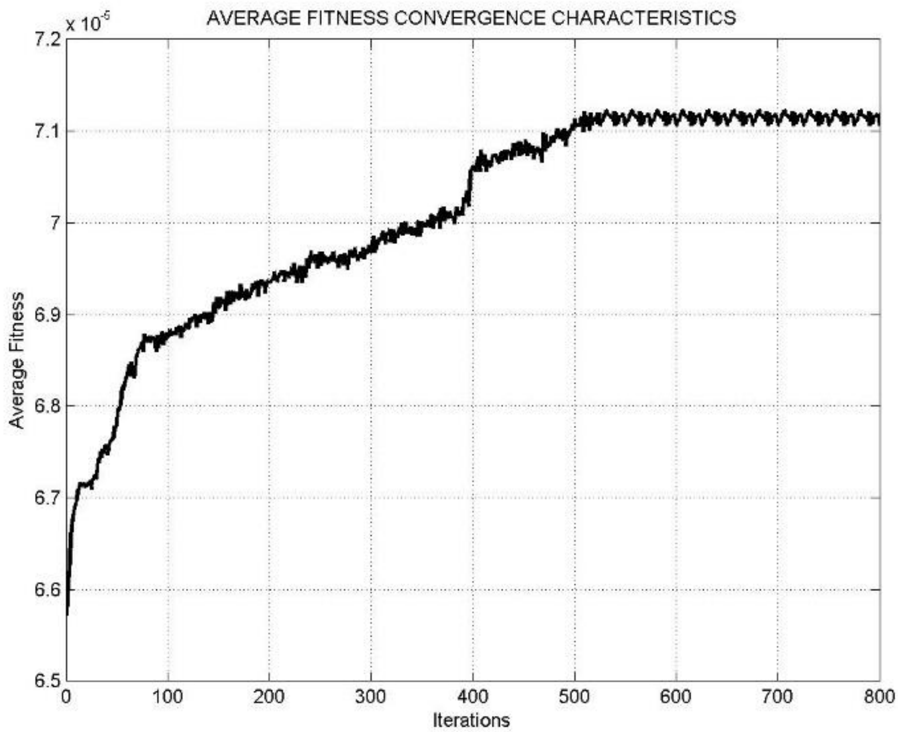


Figure 4.12 Commercial average fitness convergence characteristics

C. Industrial Area

The number of devices available for control in the industrial area is the smallest among all three areas; however, the devices have largest consumption ratings and longest consumption periods. The consumption patterns of the devices in this area are given in Table IV. The reason for a small number of devices available for control can be attributed to the fact that most of the industrial loads are critical and cannot be subjected to load control. The control periods of the devices are similar to those in the other two areas. There are over 100 controllable devices belonging to 6 different types.

Table 4.5 Hourly Consumption of Industrial Device

Device Type	Hourly Consumption of Device (kW)						Number Devices
	1st Hr	2nd Hr	3rd Hr	4th Hr	5th Hr	6th Hr	
Water Heater	12.5	12.5	12.5	12.5	-	-	39
Welding Machine	25.0	25.0	25.0	25.0	25.0	-	35
Fan/AC	30.0	30.0	30.0	30.0	30.0	-	16
Arc Furnace	50.0	50.0	50.0	50.0	50.0	50.0	8
Induction Motor	100	100	100	100	100	100	5
DC Motor	150	150	150	-	-	-	6
Total	-	-	-	-	-	-	109

The load pattern has been analysed with and without using DSM, is shown in the Figure 4.13. It can be seen that the peak loads have been shifted to off peak periods with the implementation of DSM. The utility bill of the industrial area reduces from Rs.5,71,200 to Rs.4,76,210 with demand side management strategy, resulting in about 16.62% reduction in the operating cost.

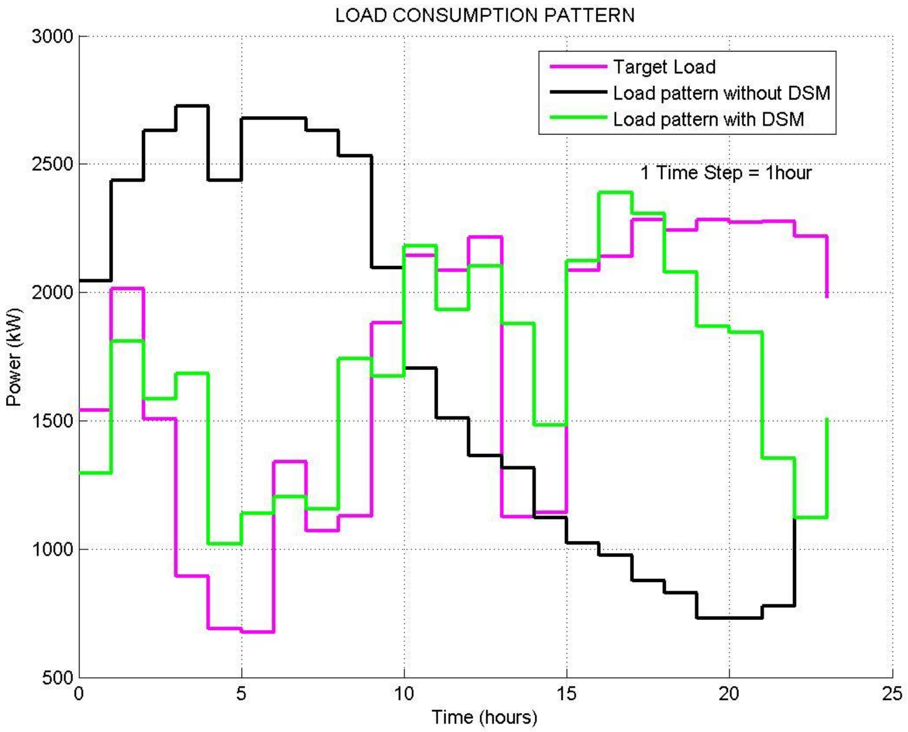


Figure 4.13 Industrial load consumption pattern

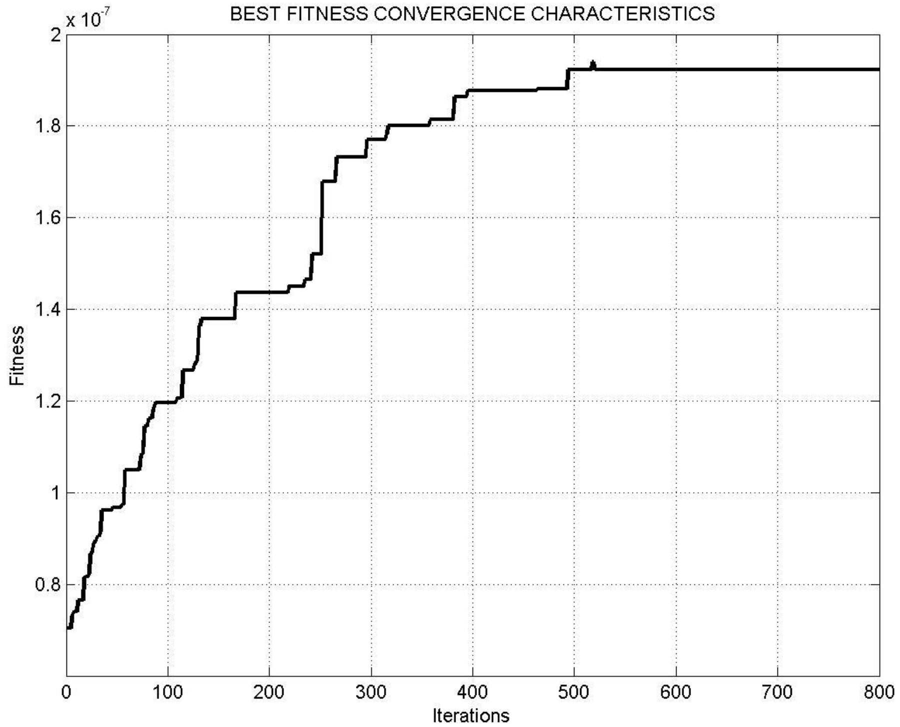


Figure 4.14 Industrial best fitness convergence characteristics

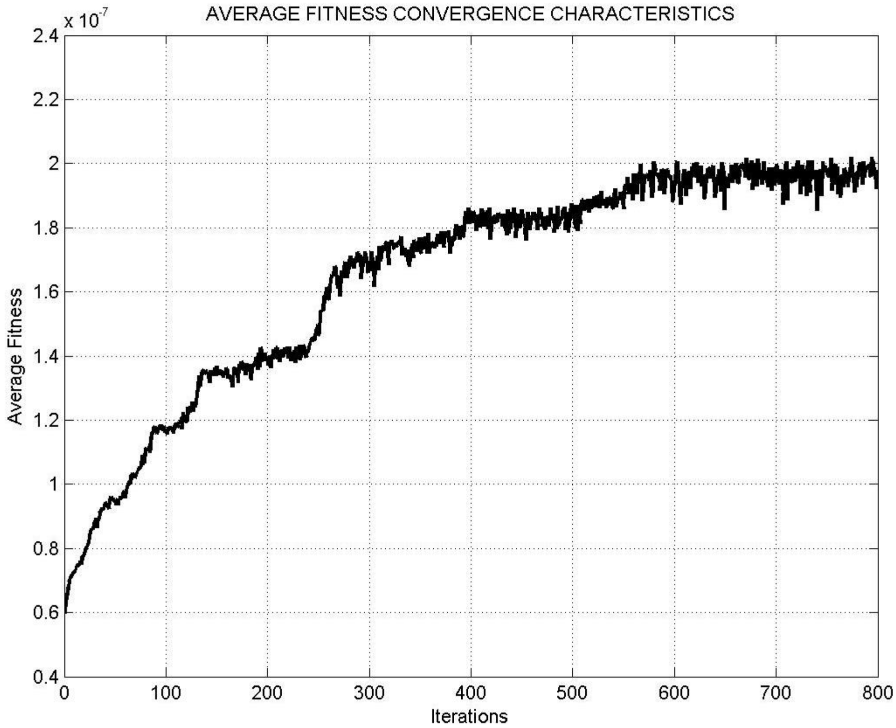


Figure 4.15 Industrial Average fitness convergence characteristics

3.2 TEST SYSTEM SUMMARY

Thus, from the analysis of DSM implementation to this test system, it can be inferred that on shifting the peak loads to off peak periods, the cost has significantly reduced, for various types of consumers which is shown in the Table 4.6.

Table 4.6 Test system results

Inference	Residential	Industrial	Commercial
Peak Reduction (%)	7.78	13.87	5.28
Cost (Rs)	2,30,300	5,71,200	3,62,660
Cost with DSM (Rs)	2,23,420	4,76,210	3,47,600
Cost Reduction (%)	2.98	16.62	4.15

CHAPTER 5

CAMPUS LOAD PROFILE STUDY

5.1 INTRODUCTION

System load profile can be monitored and analysed at different points of the electrical system at the utility end or at the customer end. Extracting real-time information from different locations is very expensive, but it can result in the collection of the most detailed information to understand consumer and system behaviour. Aggregate Load Profile consumption information is important for the electric utility to defer capital spending for distributed generation and electricity purchase from grid. It also specifies time intervals for campus's engagement in Demand Side Management (DSM) programs as well as defines the optimal locations and time interval to integrate renewable energy resources.

5.2 LOAD ASSUMPTION

Load forecasts have long been recognized as the initial building block for all utility planning efforts. While changing market structures have altered the types of forecasts that are most useful, the link between sound evaluation and design of infrastructure improvements is irreducible. Physical system planners condition their alternatives on future views regarding load levels and locations. Financial planners tie both revenue and expense forecasts to expected future energy sales and peak demands. Although load forecast is necessary for futuristic purpose, a day before load curve is chosen as a forecasted curve for the next day. Since, the forecasting techniques are hard to implement and the load pattern on a particular day is similar to other college days. Hence those assumptions are made to simplify our solution.

5.3 CAMPUS POWER LINE STRUCTURE

Input of 11 kV is supplied from the Pennalur substation to the campus and is stepped down to 440 V by using three transformers whose ratings are given in Table 5.1. The supply to all the departments are fed from the transformers using Low tension distribution panels and the details of Low Tension distribution panels are given in Table 5.2.

Table 5.1 Transformer Rating

TRANSFORMER NO:	**RATING (kVA)**
TRANSFORMER 1	500
TRANSFORMER 2	500
TRANSFORMER 3	380

Each individual department connected to independent feeder lines are given by reference numbers (PSMB), with reference (Table 5.2) to which current drawn by various departments are recorded manually for every 30 minutes’ interval and the power was calculated which is represented in Table 5.3.

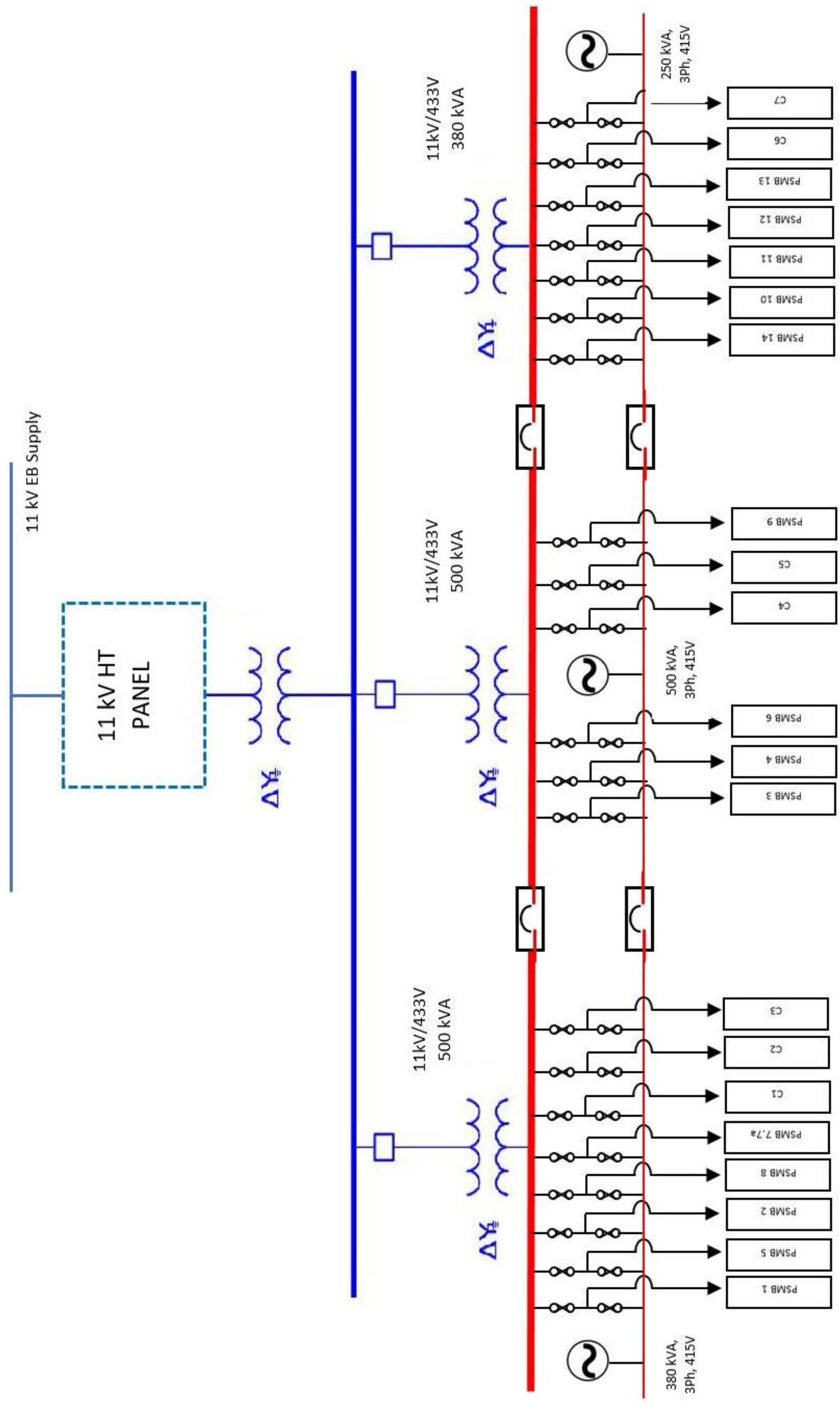


Figure 5.1 Power Structure Network

Table 5.2 LT Panel details

PSMB NO:	DEPARTMENT	PSMB NO:	DEPARTMENT
PSMB 1	EEE	PSMB 8	Canteen
PSMB 2	Mechanical	PSMB 9	Chemical
PSMB 3	CSE	PSMB 10	Hostel
PSMB 4	Physics	PSMB 11	Library
PSMB 5	Workshop	PSMB 12	Marine, Bio tech
PSMB 6	Thermal	PSMB 13	Civil
PSMB 7,7a	AC load	PSMB 14	ECE

5.4 PERIODIC DATA COLLECTION

The following data were collected from the in-campus distribution centre. Cumulative current value of the campus was calculated to arrive respective power values for the various time periods.

Figure 5.2 Low Tension Distribution Panel

Table 5.3 Periodic Data Collection

TIME	POWER(kW)	TIME	POWER(kW)
08:30-09:00	194.08	20:30-21:00	30.15
09:00-09:30	208.86	21:00-21:30	26.32
09:30-10:00	273.56	21:30-22:00	24.36
10:00-10:30	288.95	22:00-22:30	26.32
10:30-11:00	238.65	22:30-23:00	16.35
11:00-11:30	230.27	23:00-23:30	17.34
11:30-12:00	223.49	23:30-00:00	15.39
12:00-12:30	254.72	00:00-00:30	16.37
12:30-13:00	200.82	00:30-01:00	16.38
13:00-13:30	281.12	01:00-01:30	13.98
13:30-14:00	334.92	01:30-02:00	13.54
14:00-14:30	275.92	02:00-02:30	13.87
14:30-15:00	304.30	02:30-03:00	15.34
15:00-15:50	288.46	03:00-03:30	16.32
15:30-16:00	159.22	03:30-04:00	12.54
16:00-16:30	106.38	04:00-04:30	18.32
16:30-17:00	53.54	04:30-05:00	19.65
17:00-17:30	42.94	05:00-05:30	15.36
17:30-18:00	32.33	05:30-06:00	25.32
18:00-18:30	44.01	06:00-06:30	26.65
18:30-19:00	55.14	06:30-07:00	28.34
19:00-19:30	55.71	07:00-07:30	90.65
19:30-20:00	41.96	07:30-08:00	103.25
20:00-20:30	28.22	08:00-08:30	160.98

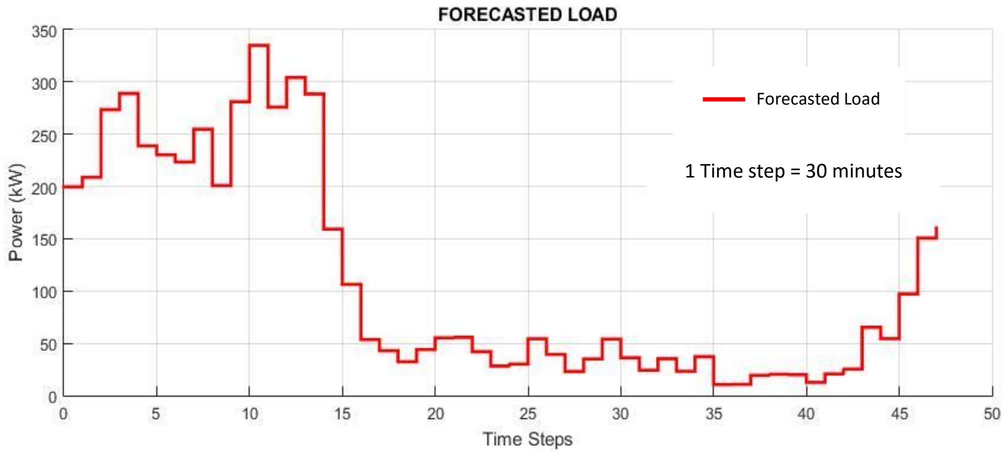


Figure 5.3 typical daily Forecasted load

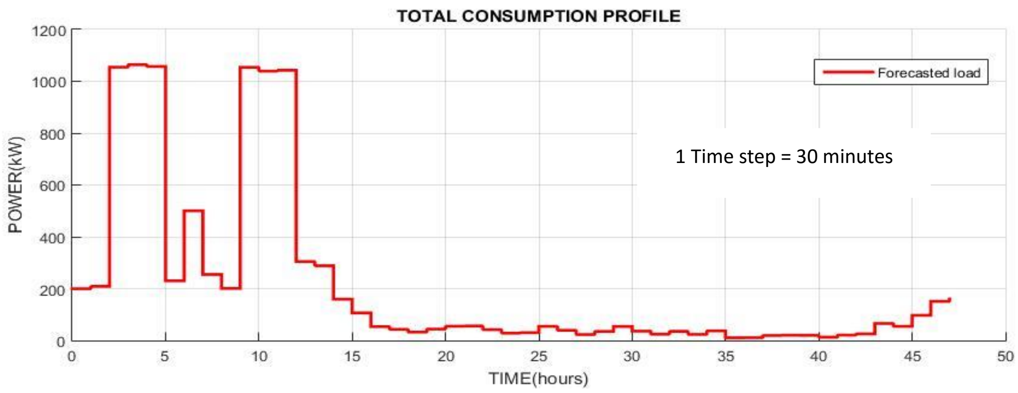


Figure 5.4 Load consumption during peak demand period

The goal of data collection is to capture quality evidence that then translates to rich data analysis and allows the building of a convincing and credible answer to questions that have been posed. While methods vary by discipline, the emphasis on ensuring accurate and honest collection remains the same. Regardless of the field of study or preference for defining data (quantitative or qualitative), accurate data collection is essential to maintaining the integrity of research.

5.5 LOAD ESTIMATION & CALCULATION

The voltage given to each department is indicated by V,

Power factor $(Cos\ \emptyset)$ = 0.95

The current for each time period is noted and is denoted by I, The Load value for each time period is calculated and denoted in kilowatt(KW) and is given by: -

$$P = V \times I \times Cos\ \emptyset \tag{5.1}$$

The power at each phase is as follows: -

Power at R phase:

$$P_R = V_R \times I_R \tag{5.2}$$

Power at Y phase:

$$P_Y = V_Y \times I_Y \tag{5.3}$$

Power at Z phase:

$$P_Z = V_Z \times I_Z \tag{5.4}$$

Since voltage is constant across the three phases,

$$V_R = V_Y = V_Z = V \tag{5.5}$$

The three phase power equation is given as,

$$P = V(I_R + I_Y + I_Z) \tag{5.6}$$

There are few important terms which must be understood before performing the load estimation, and therefore the terms are explained in detail below: -

1. Connected load

    - It is the Sum of all the loads connected to the electrical system, usually expressed in watts.

2. Demand load

    - It is The electric load at the receiving terminals averaged over a specified demand interval of time, usually 15 min., 30 min., or 1 hour based upon the particular utility's demand interval. Demand may be expressed in amperes, kilo-amperes, kilo-watts or kilo-volt-amperes.

3. Demand Interval

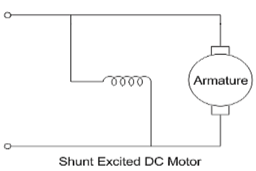
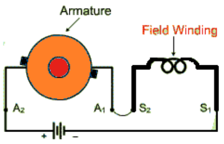
    - It is The period over which the load is averaged, usually 15 min., 30 min., or 1 hour.

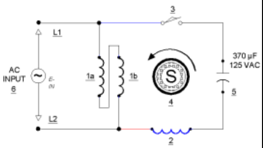
4. Maximum demand

- It is The greatest of all demands that have occurred during a specified period of time such as 5 minutes, 15 minutes, 30 minutes or one hour. For utility billing purposes the period of time is generally one month.

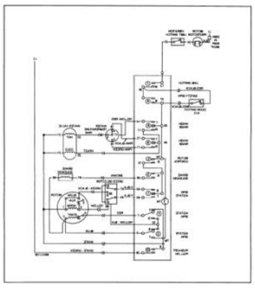
5.6 LOAD CLASSIFICATION

Table 5.4 Classification of controllable loads

Device name	Picture Representation	Description	No. of devices	Rating (Kw)
DC Shunt motor		A shunt DC motor connects the armature and field windings in parallel or shunt with a common D.C. power source. This type of motor has good speed regulation even as the load varies, but does not have the starting torque of a series DC motor.	6	2.42
DC Series motor		A series wound dc motor like in the case of shunt wound dc motor or compound wound dc motor falls under the category of self-excited dc motors, and it gets its name from the fact that the field winding in this	1	3.73

Device name	**Picture Representation**	**Description**	**No. of devices**	**Rating (Kw)**
		case is connected internally in series to the armature winding		
Induction Motor		An induction or asynchron ous motor is an AC electric motor in which the electric current in the rotor needed to produce torque is obtained by electro - magnetic induction from the magnetic field of the stator winding.	20	3.17
Lathe Machine		A lathe is a machine tool that rotates the work piece on its axis to perform various operations such as cutting, sanding, knurling, drilling, or deformation, facing, turning, with tools that are applied to the work piece to create an object with symmetry about an axis of rotation.	10	2.238
Pedestal Drilling Machine		A drill is a tool fitted with a cutting tool attachment or driving tool attachment,	3	0.80

Device name	Picture Representation	Description	No. of devices	Rating (Kw)
		usually a drill bit or driver bit, used for boring holes in various materials or fastening various materials together with the use of fasteners. The attachment is gripped by a chuck at one end of the drill and rotated while pressed against the target material		
Roll Turning Lathe Model		The Roll Turning Lathe Machines provided by us are widely used for proof and finish machining in rolling mills, cement plants, paper plants and heavy industries. The Roll Turning Lather machines offered by us are facilitated with power drives that enable carbide tipped tools to be used to their full capacity.	1	3.32
Cutter Grinder		A tool and cutter grinder is used to sharpen milling Cutters and tool bits along with a host of other cutting tools. It is an extremely	2	0.373

Device name	Picture Representation	Description	No. of devices	Rating (Kw)
		versatile machine used to perform a variety of grinding operations: surface, cylindrical, or complex shapes		
Welding machine		A welding power supply is a device that provides an electric current to perform welding.	5	8.46
Washing machine		The term is mostly applied to machines that use water as opposed to dry cleaning (which uses alternative cleaning fluids, and is performed by specialist businesses) or ultrasonic cleaners	50	0.5

5.7 FLEXIBILITY FACTOR

Flexibility factor is the maximum delay allowed for a device to shift its operation to a different time. It differs for each device type because of the difference in their operation time.

5.8 BACK UP UTILITY DEVICE

5.8.1 Photo - Voltaic Array

Photovoltaics (PV) is the name of a method of converting solar energy into direct current electricity using semiconducting materials that exhibit the photovoltaic effect, a phenomenon commonly studied in physics, photochemistry and electrochemistry. A photovoltaic system employs solar panels composed of a number of solar cells to supply usable solar power. Solar PV panels can reduce electricity bills as the electricity provided by the panels is entirely free. Colleges will only have to pay for electricity they take from the mains when solar panels cannot provide an adequate level of power. The total installed capacity of the existing photo-voltaic plant is 35MW.

Figure 5.5 Photovoltaic Array installed in the campus

5.8.2 Diesel Generator

A diesel generator is the combination of a diesel engine with an electric generator (often an alternator) to generate electrical energy. This is a specific case of engine-generator. A diesel compression-ignition engine often is designed to run on fuel oil, but some types are adapted for other liquid fuels or natural gas. Diesel generating sets are used in places without connection to a power grid, or as emergency power-supply if the grid fails, as well as for more complex applications such as peak-lopping, grid support and export to the power grid. Power is generated by using DG generators and Solar panels and these devices are used whenever there is a power shutdown in general. The details of DG generators available at the campus premises are given in the Table 5.5

Table 5.5 DG Set Rating

UTILITY DEVICE	**RATING**
DG Generator 1	250 kVA
DG Generator 2	380 kVA
DG Generator 3	500 kVA

5.9 CAMPUS TARGET LOAD FIXING

Education institution follows flat tariff for electricity. Tracking dynamic pricing is difficult in this scenario, Hence, we divide the time period into four phases. For college campus objective curve is fixed by averaging the load for the given time period and the equation is,

$$Objective(t) = \sum_{i=1}^{phases} Load\ factor(i) \times Maximum\ demand(i) \tag{5.7}$$

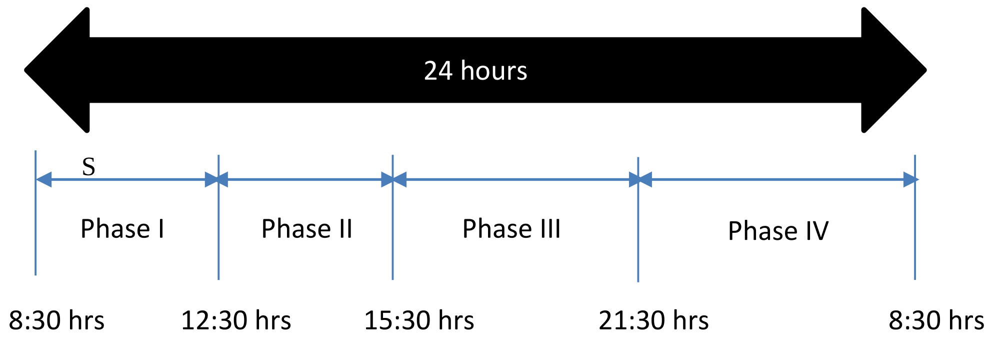


Figure 5.6 Power split up

Table 5.6 Consumption split up

PHASE NO:	TIME	POWER(kW)
I	08:30 – 12:30	530.042
II	13:00 – 15:30	646.961
III	16:00 – 21:30	48.666
IV	22:00 – 08:00	44.543

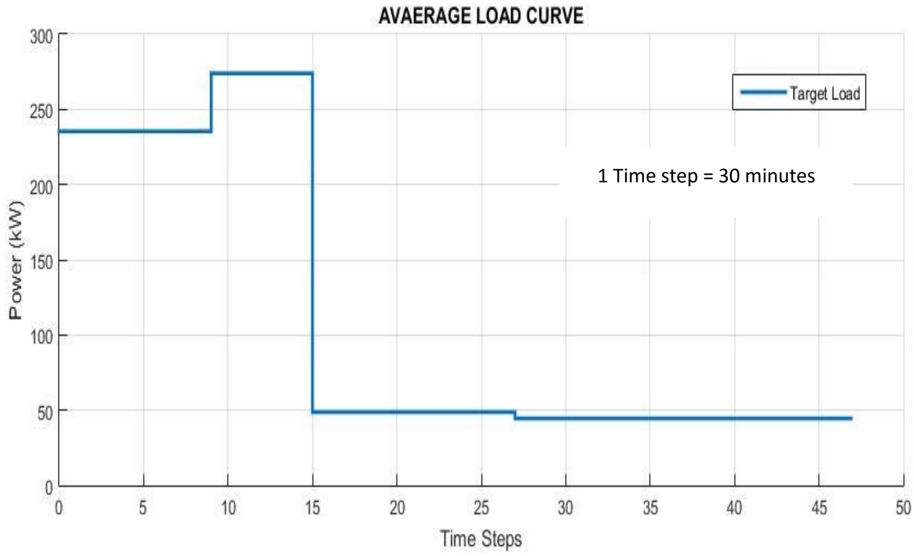


Figure 5.7 Target Load during semester practical

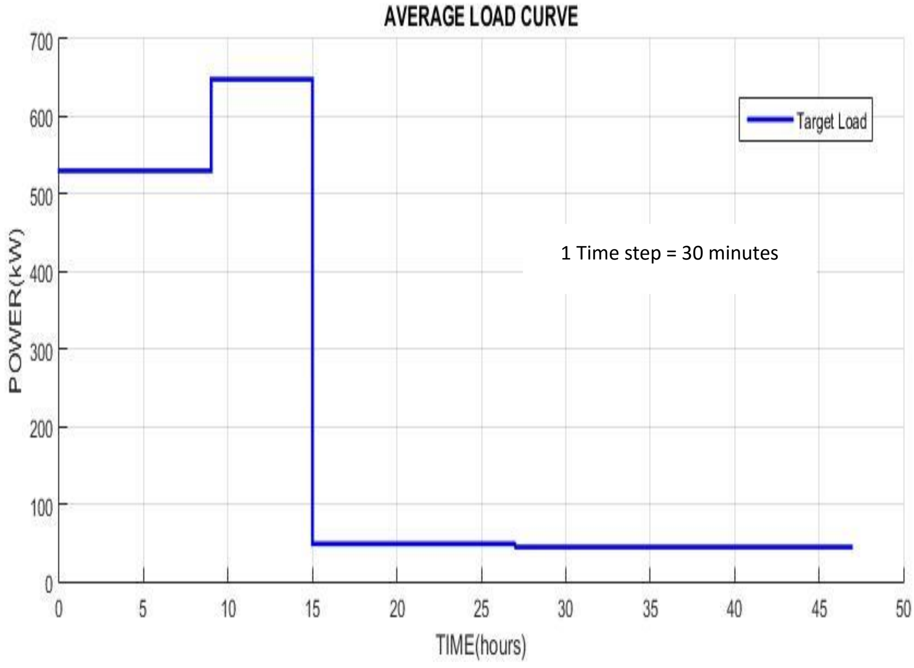


Figure 5.8 Typical target load

Thus this chapter dealt with the campus load profile study and the capacities of existing assets such as Photo Voltaic Array and Diesel generators. The target load curve has also been derived using the average load technique.

CHAPTER 6

CAMPUS DEMAND SIDE MANAGEMENT

6.1 INTRODUCTION

Simulations carried out for a university infrastructure, utilizing the existing photo-voltaic array dg generators. These existing assets are treated as a local grid and evaluated for five different operational scenarios: -

- SCENARIO 1 – Primary Supply alone
- SCENARIO 2 – DSM during peak demand hours
- SCENARIO 3 – Primary Supply with PV Integration
- SCENARIO 4 – DSM with PV during Peak demand hour
- SCENARIO 5 – Diesel Generator with PV Integration

6.2 **SCENARIO 1**: Primary Supply alone

Simulations carried out for a system model powered solely by Primary power supply. This model excludes the existing solar panel and Diesel Generators. The results obtained on implementing DSM Strategy is shown in Figure 6.1. Best fitness and average fitness convergence characteristics are also shown in Figure 6.2 and 6.3.

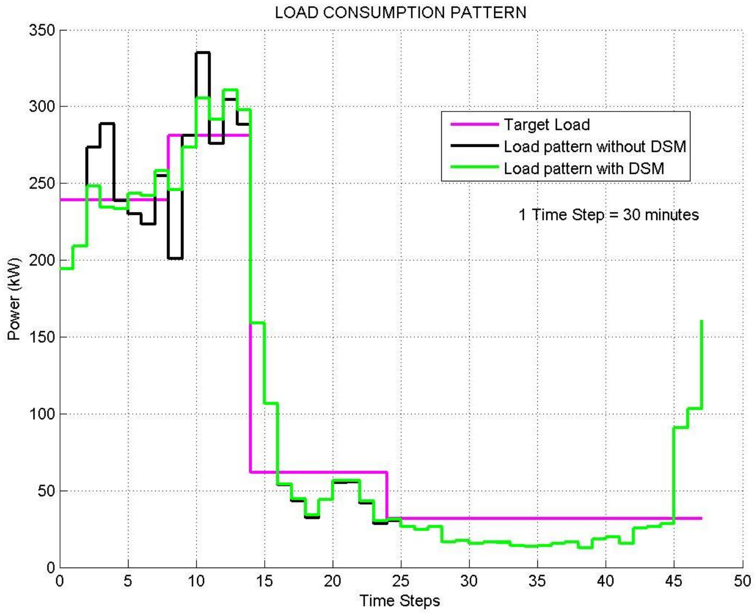


Figure 6.1 Load consumption pattern

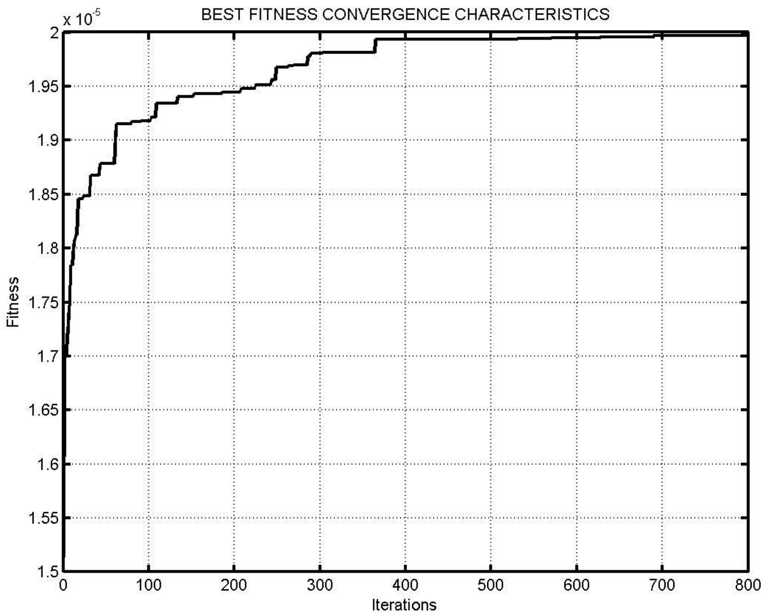


Figure 6.2 Average fitness convergence characteristics

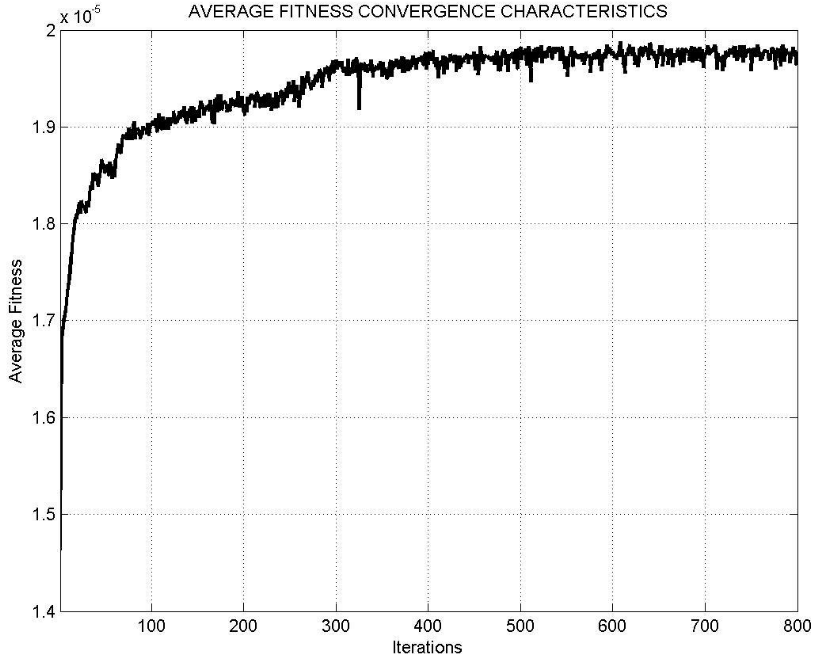


Figure 6.3 Best fitness convergence characteristics

The load pattern has been analysed with and without using DSM, is shown in the Figure 6.1. It can be seen that during time interval 2.00 – 2.30 (timesteps 4-5), the peak demand of 334.12kW is significantly reduced to 305.27kW with the implementation of DSM. Thus it can be inferred that these peak loads have been shifted to off peak periods.

6.3 **SCENARIO 2:** DSM during peak demand hours

It was observed that, the maximum demand exceeds the permitted demand value, during end semester examinations. On doing so, penalty charges are added to the bill, with leads to hike in total consumption charge. This kind of critical situation is avoided by the implementation of demand side management.

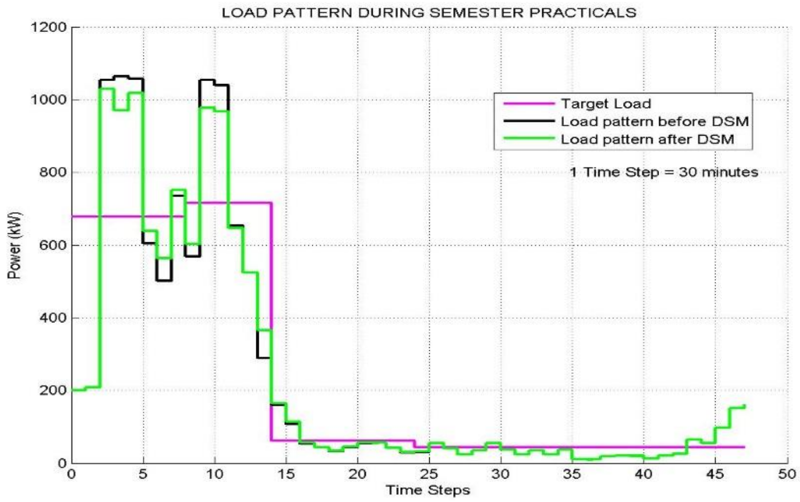


Figure 6.4 Load Pattern during peak demand hours

The load pattern has been analysed with and without using DSM, is shown in the Figure 6.4. It can be seen that during time interval 9.30 – 11.0 (timesteps 2-5), maximum allowable demand of 1035kW is exceeded and with the implementation of DSM these peak loads have been shifted to off peak periods. This scenario considerers primary supply alone.

6.4 SCENARIO 3: Primary Supply with PV Integration

Simulations carried out for a system model powered by TNEB and existing 35kW PV Array. This model excludes the usage of existing diesel generators. The results obtained on implementing DSM Strategy is shown in Figure 6.4. Best fitness and average fitness convergence characteristics are also shown in Figure 6.5 and 6.6.

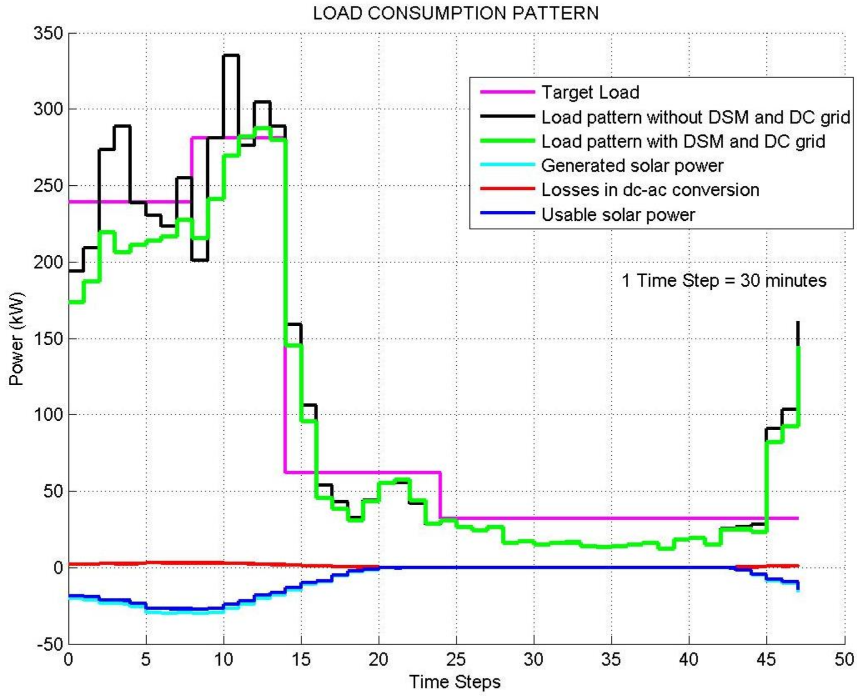


Figure 6.5 Load consumption pattern

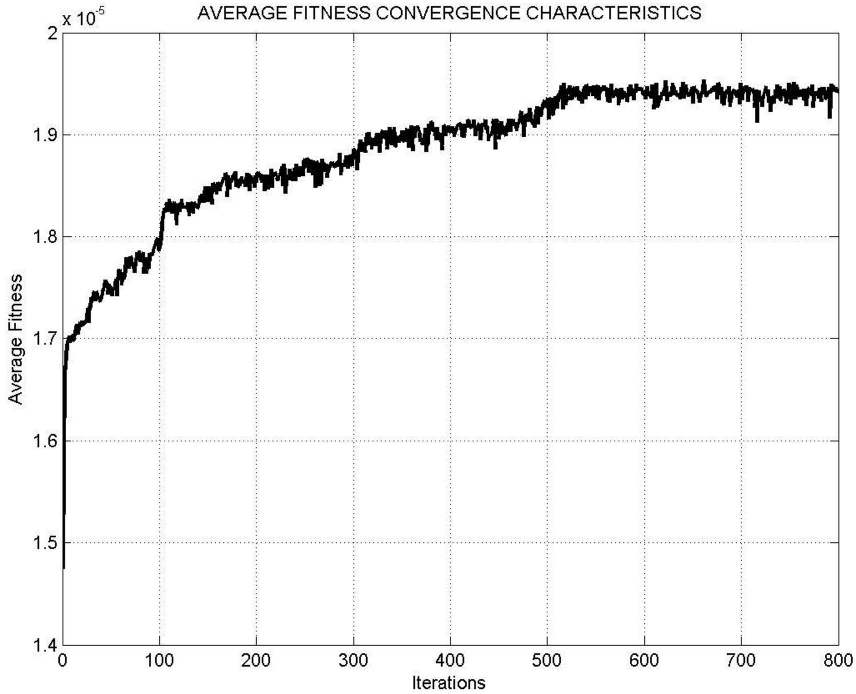


Figure 6.6 Average fitness convergence characteristics

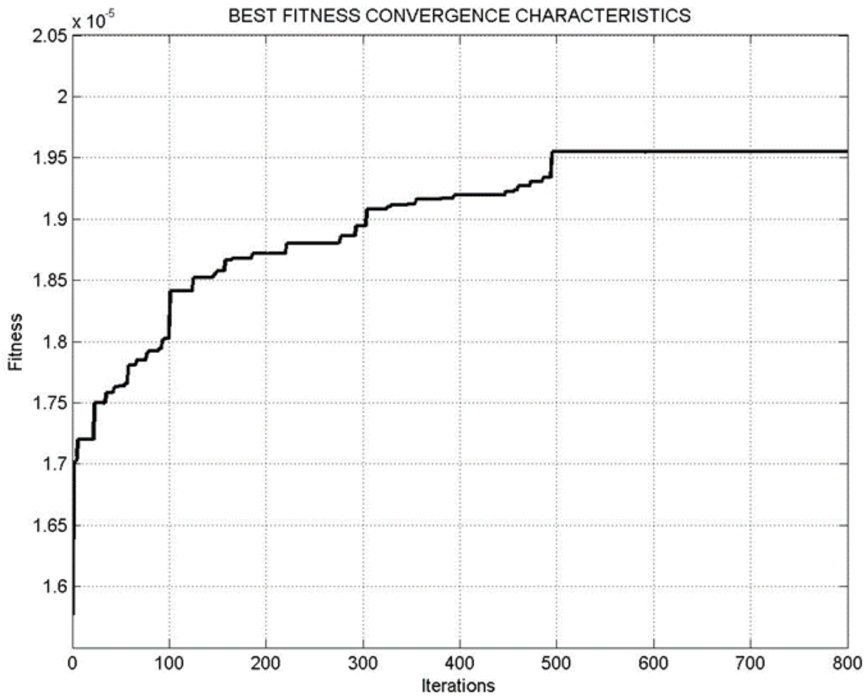


Figure 6.7 Best fitness convergence characteristics

Table 6.1 Load Factor Compensation

S No	**Time**	**Load Factor before DSM (%)**	**Load Factor after DSM (%)**	**Peak reduction (%)**	**Over all Peak Reduction (%)**
1	08:30 – 12:30	82.75	90.12	10.57	7.26
2	13:00 – 15:30	83.87	92.55	7.26	
3	16:00 – 21:30	38.90	39.50	0	
4	22:00 – 08:00	19.75	19.78	0	

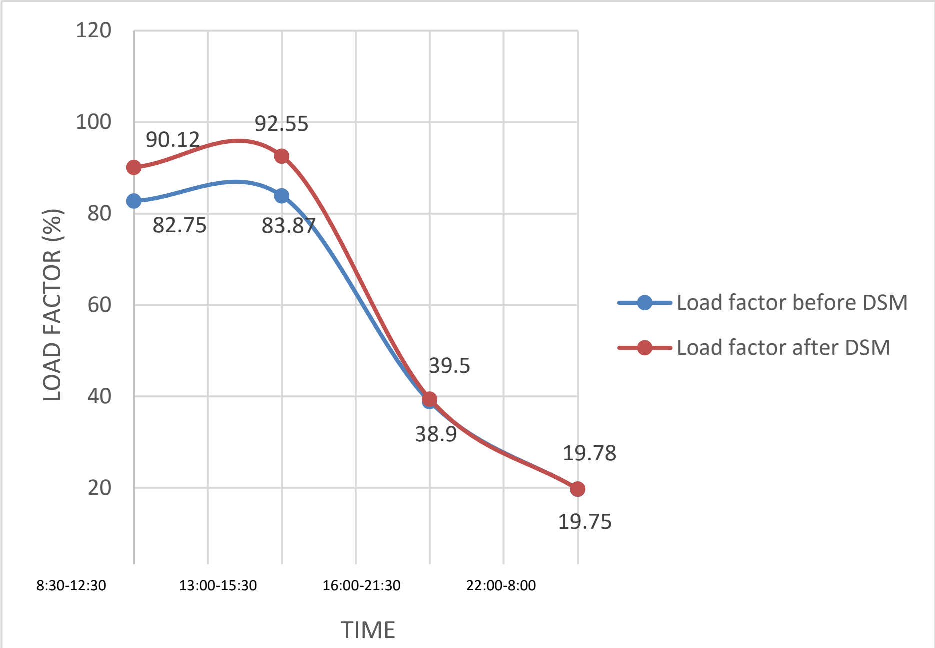


Figure 6.8 Load Factor with and without DSM

The load pattern has been analysed with and without using DSM, is shown in the Figure 6.8. It can be seen that during time interval 2.00 – 2.30 (timesteps 4-5), the peak demand of 334.12kW is significantly reduced to 270.34kW with the implementation of DSM. Thus it can be inferred that these peak loads have been shifted to off peak periods. This scenario considers primary supply and the integration of existing 35kW Photovoltaic array installed.

6.5 **SCENARIO 4:** DSM with PV during Peak demand hour

The scenario 3 is extended with solar integration and applied during peak demand hours, this usually occurs during the end semester examination. The results obtained are shown in Figure 6.9.

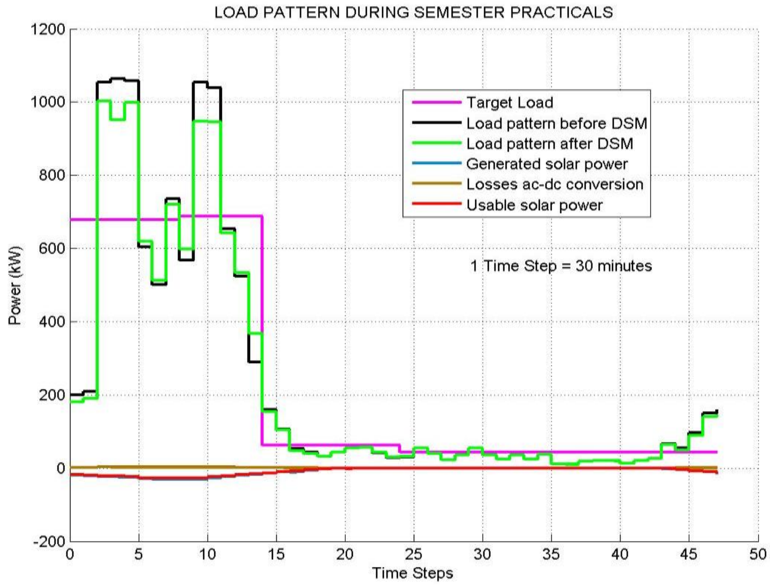


Figure 6.9 DSM with PV integration during peak demand hours

The load pattern has been analysed with and without using DSM, is shown in the Figure 6.9. It can be seen that during time interval 10.00 – 10.30 (timesteps 10-11), the peak demand of 1067.12kW is significantly reduced to 1000.12kW with the implementation of DSM (Maximum Demand – 1035kW). This is considering primary supply and the integration of existing 35kW Photovoltaic array installed.

6.5 **SCENARIO 5:** Diesel Generator with PV Integration

Simulations carried out for a system model powered by existing diesel generators and existing 35kW PV Array alone. This model excludes the usage of purchased power from TNEB. The results obtained on implementing DSM Strategy is shown in Figure 6.4.

Consumption of diesel for every hour by the DG generators 1, 2 and 3 are given in Table 6.2. Cost of diesel per litre on the day of data collection was ₹49

Table 6.2 DG Diesel Consumption

GENERATORS	**Diesel Consumed (ltr)**
DG Generator 1 (250 kVA)	55
DG Generator 2 (380 kVA)	60
DG Generator 3 (500 kVA)	70

For the optimal use of DG generator, unit commitment problem is solved and based on the demand, DG generators are scheduled.

Full Load Average Production Cost $\boldsymbol{FLAPC = \frac{Fuel\ cost \times Fuel\ Consumed}{Power\ at\ Full\ load}}$

$$\boldsymbol{Base\ Charge = (30\%(Fuel\ consumed) \times Fuel\ Cost\ per\ litre)}$$

Table 6.3 Full Load Average Production Cost

Generator	**FLAPC(Rs)**	**Base Charge (Rs)**	**Incremental cost (Rs)**
1	13.475	808.5	9.43
2	9.671	882	6.77
3	8.575	1029	6

A strict priority order for these units, based on the average production cost would order them as shown in Table 6.4

Table 6.4 FLAPC Priority Table

DG GENERATOR	**FLAPC(Rs)**	**Min kW**	**Max kW**
3	8.575	120	450
2	9.671	90	340
1	13.475	60	230

The commitment scheme would simply use only one of the following combinations as shown in Table 6.5 depending on their requirement.

Table 6.5 DG Generator Selection

Combination	**MIN kW from combination**	**MAX kW from combination**
3+2+1	270	910
3+2	210	710
3	120	400

On solving this unit commitment problem, it is inferred that the reduction in overall operating generator cost could be cut down, when the generators are start depending on the demand. This leads to the efficient usage of power. From Figure 6.10, it is seen that the overall operational cost with the integration of Diesel Generators and photovoltaic panels, the peak is reduced by 3.65%.

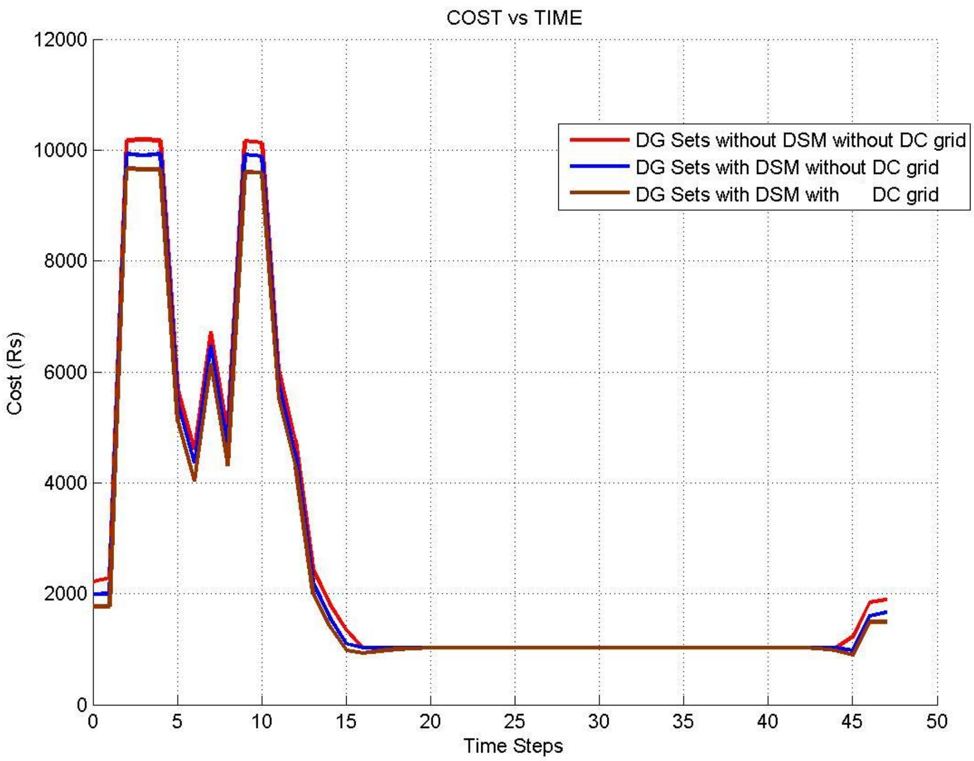


Figure 6.10 Diesel Generator overall operational cost

In this model the entire campus is powered independently using the existing assets (DG Generators & PV Panels). From the above graph, it is inferred that on applying DSM strategy on the integration of PV panels with diesel generators significantly reduces operational cost.

Thus, in this chapter, simulations carried out for a university infrastructure were discussed in detail. Results shows under proper utilization of existing photo-voltaic array and DG generators the overall operational costs could be brought down.

CHAPTER 7

CONCLUSION & FUTURE SCOPE

7.1 CONCLUSION

The proposed strategy is a generalized technique based on load shifting, which has been mathematically formulated as a minimization problem. A heuristic based evolutionary algorithm is developed for solving the problem. The simulation outcomes carried out for a campus infrastructure shows that the proposed algorithm is able to handle a large number of controllable devices of several types, and achieves substantial savings while reducing the peak load demand.

Due to the flat tariff structures for educational institutions, the objective curve is fixed by average load technique. Before Load shifting, the load factor is 30.9 percent whereas after applying DSM, it is found that the load factor is improved and load curve peak is reduced. Load factor improvement is seen only in few time periods (i.e. 8:30 to 12:30 and 13:00 to 15:30). This is due to considerable amount of controllable loads present only in those time periods. Peak reduction is zero due to the absence of controllable loads during 14:00 to 8:00. Only lighting and fan loads dominates after college hours which are not included in the controllable loads list. Hence over all peak reduction for a day is found to be 7.26 percent and load factor is 33.4 percent, which is shown in Table

7.1. In addition to this, proper utilization & allocation of local power generating units such as photovoltaic panels and DG Generators, which is also considered in this project leads to substantial amount of savings.

Table 7.1 Peak Reduction

	Peak Reduction in %	**Cost reduction (Rs)**	**Cost reduction in %**
Non - Peak demand hours			
Primary supply alone	4.545	nil	nil
Primary supply with PV Integration	14.1184	nil	nil
Peak demand hours			
Primary supply alone	3.32	14,960.00	11.39
Primary supply with PV Integration	6.09	37,400.00	28.48
DG with PV Integration	5.762	4,699.00	3.65

7.2 MODEL HIGHLIGHTS

- Efficient allocation and usage of available DG Sets, which inturn reduces fuel cost, pollution, lifespan and maintenance.
- Best utilization of existing 35kW Photovoltaic panels.
- Support for future expansion of renewable assets.

7.3 FUTURE SCOPE

As Demand Side Management proves to have better performance and peak curve reduction. The energy consumers of the country are brought to an awareness and influences a deliberate method to lower the demand for electricity, ensuring the stability on the grid. This also develops efficient utilization for electricity and significant drop in emission of harmful gases into the atmosphere curtailing the global warming process. The further research of this approach should continue as Energy efficiency (both supply & demand-side) should take priority over development of renewables, and moreover the large scale expansion of demand side power utilization requires better power balance which could be brought into by implementation advanced DSM strategies.

APPENDIX 1

CODING FOR DEMAND SIDE MANAGEMENT

```
price=[12 9.19 12.27 20.69 26.82 27.35 13.81 17.31 16.42 9.83 8.63 8.87
8.35 16.44 16.19 8.87 8.65 8.11 8.25 8.10 8.14 8.13 8.34 9.35];
t=[0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23];
solar=[45.5 49.2 50.23 52.34 55.9 57.4 52.1 50 48.1 37.9 29.1 15.0 6.13
0 0 0 0 0 0 0 0 17.42 30.42 40.98];
n=input('Enter the population number:');
filename = 'inputfile.xlsx';
sheet = 1;
Total_devices = xlsread(filename,sheet,'B1');
[num,txt,raw]= xlsread(filename,sheet,'A3:A8');
Device_type=txt;
Total_Device_types=6;
Device_count= xlsread(filename,sheet,'B3:B8');
Starting_time= xlsread(filename,sheet,'C3:C8');
Connection_time= xlsread(filename,sheet,'K3:K8');
Connection_power= xlsread(filename,sheet,'E3:J8');
sheet=2;
pload= xlsread(filename,sheet,'A2:A25');
maxi_price=max(price);
sum=0;lsum=0;
for i=1:24
```

```
    sum=sum+price(i);
    lsum=lsum+pload(i);
end
avg=sum/24;
for i=1:24
    obj(i)=(avg/maxi_price)*(1/price(i))*lsum;
end
for i=1:n
    for j=1:24
        energy(i,j)=pload(j)-solar(j);
    end
end
%Device parameters
for m=1:n
    k=1;
    for i=1:Total_Device_types
        for j=1:Device_count(i)
            Device(m,k).Device_name=Device_type(i);
            Device(m,k).Device_number=j;
            Device(m,k).Start_time=Starting_time(i);
            Device(m,k).Operation_time=Starting_time(i);
            Device(m,k).Connection_period=Connection_time(i);
            for q=1:Connection_time(i)
                Device(m,k).Connection_energy(q)=Connection_power(i,q);
            end
            if(24-Starting_time(i)-Connection_time(i))>12
```

```
            Device(m,k).max_delay=12;
          else
            Device(m,k).max_delay=24-Starting_time(i)-
Connection_time(i);
          end

Device(m,k).max_Start_time=Device(m,k).Start_time+Device(m,k).ma
x_delay;
          Device(m,k).apparent_min_delay=Device(m,k).Start_time-
Device(m,k).Operation_time;
Device(m,k).apparent_max_delay=Device(m,k).Start_time+Device(m,k
).max_delay-Device(m,k).Operation_time;
          k=k+1;
       end
    end
end
%Initialization
for i=1:n
   for j=1:Total_devices

Device(i,j).Delay=floor(Device(i,j).apparent_min_delay+(Device(i,j).ap
parent_max_delay-Device(i,j).apparent_min_delay)*rand());
   end
end

%Fittness
```

```
for iter=1:800
    for i=1:n
        for k=1:Total_devices
            for j=1:24
                if(j==Device(i,k).Operation_time)
                    for l=1:Device(i,k).Connection_period
                        energy(i,j+l-1)=energy(i,j+l-1)-
Device(i,k).Connection_energy(l);
                        energy(i,Device(i,k).Start_time+Device(i,k).Delay+l-
1)=energy(i,Device(i,k).Start_time+Device(i,k).Delay+l-
1)+Device(i,k).Connection_energy(l);
                    end
                end
            end
        end
    end
    for i=1:n
        for j=1:Total_devices

Device(i,j).Operation_time=Device(i,j).Start_time+Device(i,j).Delay;
        end
    end
      total=0;
    for i=1:n
        error(i)=0;
        for j=1:24
```

```
        error(i)=error(i)+power((obj(j)-energy(i,j)),2);
        fitness(i)=(1/(1+error(i)));
    end
    total=fitness(i)+total;
end
avg_fitness(iter)=total/n;
for i=1:n
    for j=i+1:n
        if(fitness(i)>fitness(j))
            temp=fitness(i);
            fitness(i)=fitness(j);
            fitness(j)=temp;
            for m=1:Total_devices
                tmp=Device(i,m);
                Device(i,m)=Device(j,m);
                Device(j,m)=tmp;
            end
            for m=1:24
                temp=energy(i,m);
                energy(i,m)=energy(j,m);
                energy(j,m)=temp;
            end
        end
    end
end
for i=1:n
```

```
    prob(i)=fitness(i)/total;
end
for i=1:n
    c(i)=0;
    for j=1:i
        c(i)=c(i)+prob(j);
    end
end
for i=1:n
    ra(i)=rand();
end
for i=1:n
    for j=1:n
        if(ra(i)<c(j))
            for m=1:Total_devices
                newchrome(i,m)=Device(j,m);
            end
            for m=1:24
                newchrome_energy(i,m)=energy(j,m);
            end
            break;
            new_fitness(i)=fitness(j);
        end
    end
end
pc=0.9;q=1;
```

```
for i=1:n
    ra(i)=rand();
    if(ra(i)<pc)
        parentindex(q)=i;
        for m=1:Total_devices
            parent(q,m)=newchrome(i,m);
        end
        for m=1:24
            parent_energy(q,m)=newchrome_energy(i,m);
        end
        q=q+1;
    end
end
q=q-1;
z=1;
vmin=0.75;vmax=1.5;
for i=1:(q-1)
    for j=1:Total_devices
        u=rand();
        child(z,j)=parent(i,j);
        for m=1:24
            child_energy(z,m)=parent_energy(i,m);
        end
        child(z,j).Delay=floor((u*parent(i,j).Delay)+((1-
u)*parent(i+1,j).Delay));
        if (child(z,j).Delay>child(z,j).apparent_max_delay)
```

```
    child(z,j).Delay=child(z,j).apparent_max_delay;
end
if (child(z,j).Delay<child(z,j).apparent_min_delay)
    child(z,j).Delay=child(z,j).apparent_min_delay;
end
k1(z,j)=child(z,j).Delay;
u=rand();
child(z+1,j)=parent(i+1,j);
for m=1:24
    child_energy(z+1,m)=parent_energy(i+1,m);
end
child(z+1,j).Delay=floor(((1-
u)*parent(i,j).Delay)+((u)*parent(i+1,j).Delay));
if (child(z+1,j).Delay>child(z+1,j).apparent_max_delay)
    child(z+1,j).Delay=child(z+1,j).apparent_max_delay;
end
if (child(z+1,j).Delay<child(z+1,j).apparent_min_delay)
    child(z+1,j).Delay=child(z+1,j).apparent_min_delay;
end
k1(z+1,j)=child(z+1,j).Delay;
        u=rand();
child(z+2,j)=parent(i,j);
for m=1:24
    child_energy(z+2,m)=parent_energy(i,m);
end
```

```
child(z+2,j).Delay=floor(0.5*(parent(i,j).Delay+parent(i+1,j).Delay));
        if (child(z+2,j).Delay>child(z+2,j).apparent_max_delay)
            child(z+2,j).Delay=child(z+2,j).apparent_max_delay;
        end
        if (child(z+2,j).Delay<child(z+2,j).apparent_min_delay)
            child(z+2,j).Delay=child(z+2,j).apparent_min_delay;
        end
        k1(z+2,j)=child(z+2,j).Delay;
        u=rand();
        child(z+3,j)=parent(i+1,j);
        for m=1:24
            child_energy(z+3,m)=parent_energy(i+1,m);
        end
child(z+3,j).Delay=floor(0.5*((u*(parent(i,j).Delay+parent(i+1,j).Delay)
)+((1-
u)*(child(z+3,j).apparent_max_delay+child(z+3,j).apparent_min_delay)
)));
        if (child(z+3,j).Delay>child(z+3,j).apparent_max_delay)
            child(z+3,j).Delay=child(z+3,j).apparent_max_delay;
        end
        if (child(z+3,j).Delay<child(z+3,j).apparent_min_delay)
            child(z+3,j).Delay=child(z+3,j).apparent_min_delay;
        end
        k1(z+3,j)=child(z+3,j).Delay;
        end
```

```
        z=z+4;
    end

    u=rand();
    for j=1:Total_devices
            u=rand();
            child(4*q-3,j)=parent(i,j);
            for m=1:24
                child_energy(4*q-3,m)=parent_energy(i,m);
            end
            child(4*q-3,j).Delay=floor((u*parent(i,j).Delay)+((1-
u)*parent(i+1,j).Delay));
            if (child(4*q-3,j).Delay>child(4*q-3,j).apparent_max_delay)
                child(4*q-3,j).Delay=child(4*q-3,j).apparent_max_delay;
            end
            if (child(4*q-3,j).Delay<child(4*q-3,j).apparent_min_delay)
                child(4*q-3,j).Delay=child(4*q-3,j).apparent_min_delay;
            end
            k1(4*q-3,j)=child(4*q-3,j).Delay;

            u=rand();
            child(4*q-2,j)=parent(i+1,j);
            for m=1:24
                child_energy(4*q-2,m)=parent_energy(i+1,m);
            end
```

```
child(4*q-2,j).Delay=floor(v*((1-
u)*parent(i,j).Delay)+((u)*parent(i+1,j).Delay));
if (child(4*q-2,j).Delay>child(4*q-2,j).apparent_max_delay)
   child(4*q-2,j).Delay=child(4*q-2,j).apparent_max_delay;
end
if (child(4*q-2,j).Delay<child(4*q-2,j).apparent_min_delay)
   child(4*q-2,j).Delay=child(4*q-2,j).apparent_min_delay;
end
k1(4*q-2,j)=child(4*q-2,j).Delay;

u=rand();
child(4*q-1,j)=parent(i,j);
for m=1:24
   child_energy(4*q-1,m)=parent_energy(i,m);
end
child(4*q-
1,j).Delay=floor(v*0.5*(parent(i,j).Delay+parent(i+1,j).Delay));
if (child(4*q-1,j).Delay>child(4*q-1,j).apparent_max_delay)
   child(4*q-1,j).Delay=child(4*q-1,j).apparent_max_delay;
end
if (child(4*q-1,j).Delay<child(4*q-1,j).apparent_min_delay)
   child(4*q-1,j).Delay=child(4*q-1,j).apparent_min_delay;
end
k1(4*q-1,j)=child(4*q-1,j).Delay;

u=rand();
```

```
        child(4*q,j)=parent(i+1,j);
        for m=1:24
            child_energy(4*q,m)=parent_energy(i+1,m);
        end

child(4*q,j).Delay=floor(v*0.5*((u*(parent(i,j).Delay+parent(i+1,j).Del
ay))+((1-
u)*(child(4*q,j).apparent_max_delay+child(4*q,j).apparent_min_delay)
)));
        if (child(4*q,j).Delay>child(4*q,j).apparent_max_delay)
            child(4*q,j).Delay=child(4*q,j).apparent_max_delay;
        end
        if (child(4*q,j).Delay<child(4*q,j).apparent_min_delay)
            child(4*q,j).Delay=child(4*q,j).apparent_min_delay;
        end
        k1(4*q,j)=child(4*q,j).Delay;
    end

    for i=4*q+1:5*q
        for j=1:Total_devices
            child(i,j)=parent(i-4*q,j);
        end
        for m=1:24
            child_energy(i,m)=parent_energy(i-4*q,m);
        end
    end
```

```
for i=1:5*q
    for j=1:24
        for k=1:Total_devices
            if(j==child(i,k).Operation_time)
                for l=1:child(i,k).Connection_period
                    child_energy(i,j+l-1)=child_energy(i,j+l-1)-
child(i,k).Connection_energy(l);
                    child_energy(i,child(i,k).Start_time+child(i,k).Delay+l-
1)=child_energy(i,child(i,k).Start_time+child(i,k).Delay+l-
1)+child(i,k).Connection_energy(l);
                end
            end
        end
    end
end

for i=1:5*q
    for j=1:Total_devices
        child(i,j).Operation_time=child(i,j).Start_time+child(i,j).Delay;
    end
end

for i=1:5*q
    child_error(i)=0;
```

```
    for j=1:24
        child_error(i)=child_error(i)+power((obj(j)-child_energy(i,j)),2);
        child_fitness(i)=(1/(1+child_error(i)));
    end
end

for i=1:5*q
    for j=i+1:5*q
        if(child_fitness(i)<child_fitness(j))
            temp=child_fitness(i);
            child_fitness(i)=child_fitness(j);
            child_fitness(j)=temp;
            for m=1:Total_devices
                tmp=child(i,m);
                child(i,m)=child(j,m);
                child(j,m)=tmp;
            end
            for m=1:24
                tmp1=child_energy(i,m);
                child_energy(i,m)=child_energy(j,m);
                child_energy(j,m)=tmp1;
            end
        end
    end
end
```

```
pm=0.1;
noe=floor(n/2)*Total_devices;
mut=pm*noe;
totalmut=round(mut);
pos=floor((1+(noe-1)*rand(totalmut,1)));
row=fix(pos/Total_devices);
col=(pos-(row*Total_devices))+1;
for i=1:floor(n/2)
    for j=1:Total_devices
        for m=1:totalmut
            if((i==row(m)) && (j==col(m)))

child(i,j).Delay=floor(child(i,j).apparent_min_delay+(child(i,j).apparent
_max_delay-child(i,j).apparent_min_delay)*rand());
                if (child(i,j).Delay>child(i,j).apparent_max_delay)
                    child(i,j).Delay=child(i,j).apparent_max_delay;
                end
                if (child(i,j).Delay<child(i,j).apparent_min_delay)
                    child(i,j).Delay=child(i,j).apparent_min_delay;
                end
            end
        end
    end
end
for i=1:floor(n/2)
    for j=1:Total_devices
```

```
            Device(i,j)=child(i,j);
        end
        for m=1:24
            energy(i,m)=child_energy(i,m);
        end
    end
    super_solution=max(fitness);
    best(iter)=max(fitness);
    line(iter)=iter;
    plot(iter,super_solution,'erasemode','none');
    drawnow
end
for i=1:24
    ener(i)=energy(1,i);
end
hold on;
stairs(t,obj,'m');
stairs(t,pload,'k');
stairs(t,ener,'g');
hold off;
```

APPENDIX 2

CAMPUS UTILITY BILL

TamilNadu Generation and Distribution Corporation Ltd.

High Tension Bill (Provisional) for the Month of February - 2016

01 MAR 2016
Pennalur
Sriperumbudur Tk-602 117

SRI VENKATESWARA COLLEGE OF ENGG
PENNALUR VILLAGE
SRIPERUMPUDUR TK
CHENGAI M G R DT-60210

Service No	: 165
Bill No	: 165
Date of Bill	: 29-FEB-16
Due Date	: 06-MAR-16
Tariff App. /Bld	: IIB/IIB

Permitted MD : 1057 KVA Transformer Loss : 0 /0 . Tr. CAP. 0 KVA

DETAILS			AMOUNT (Rs.)
1. IndustrialConsumption Units @Rs	6.35per Unit	1,56,024	9,90,752.40
2. Peak Hr. Consumption Units @Rs	1.27per Unit	0	0.00
3. Night Hr Consumption 5% Rebate @Rs	6.35per Unit	0(-)	0.00
4. Quarters Consumption		0	0.00
5. Commercial Consumption		0	0.00
6. Total Energy Charges			9,90,752.40
7. Demand Charges at Rs	350.00 per KVA	980.10	3,43,035.00
8. Total Demand and Energy Charges			13,33,787.40
9. For Non-Availing the supply at the Required Voltage 11 KV at	.100 Rs. per Unit		0.00
10. Add Meter Rent			2,000.00
11. Add Belated Payment Surcharge			0.00
12. Add Extra Levy for exceeding limits			
a) Quota Consumption Units at Rs.	12.70 per Unit	0.00	
b) Quota Demand at Rs.	700.00 per KVa	0.000	0.00
c) Contracted Max. Dmd at Rs.	700.00 per KVA	0.000	0.00
d) Compensation Charges for Low PF			0.00
e) Comp. Charges for WM PF RKVAHR			0.00
f) Evening Peak Energy & Demand			0.00
13. Wind Mill Service Charge			0.00
14. Add/Less Adjustment Charge	Ty. Sy. Fixed & Energy Charges →		19,320.00
15. Harmonics Compensation Charge			0.00
16. Cross Subsidy Surcharge			0.00
17. Reliability Charge			0.00
18. Electricity Tax (incl rel. chg)			60,844.60
19. Rounding Off			0.00
20. Assessment Amount			14,15,952.00
21. Other Adjustment			0.00
22. Self Generation Tax			0.00
23. Nett Total			14,15,952.00

Rupees Fourteen Lakhs Fifteen Thousand Nine Hundred And Fifty Two Only

If the last day of the due date happens to be a holiday, the due date shall be extended till the next working day.

****** Payment of CC charges through RTOS facility shall be availed ******

T CM

H. T. BILL Working Sheet Annexure

Circle code 0411 | Circle Name CHENGALPATTU

Service No 165

Meter type Total

Reading Date 26/02/16 Meter No 1 Readtype Code RE MF : 1,200.00

	KWHR	KVAHR	RKVAHR	KVAMD
Final Reading	4,672.74	4,823.30	6.17	0.499
Initial Reading	4,541.57	4,684.60	6.14	0.000
Diff Reading	131.17	138.70	0.03	
Consumption	1,57,404	1,66,440	36	598.80

ETax calculation

Realised energy charges :	9,70,752.40
Recorded Demand charges for 598.80 :	2,09,580.00
Taxable Amt(inc. pf incentive/disincentive):	12,00,332.40
E-Tax.Amt (5%) + Old E-Tax + rel.chrg :	60,344.60

Concession, Adjustments

Adj.Affect	Adj.Not Affect
19,320.00	0.00

Adjust.Code	Description		Amount
E3	OLD ENERGY CHARGES	TY. Supply Energy charges (1380x12)	16560.00
DE	OLD TAX AMOUNT	—do— E-TY	828.00
D3	OLD DEMAND CHARGES	TY. Supply Fixed charges (8x345)	2760.00

Demand Details

Quota MD/PMD	RECMD	Days	Tot Days	MD Rate	RType
1,089.000	598.500	30	30	350.00	RE

TamilNadu Generation and Distribution Corporation Ltd.
Chengalpattu Circle
High Tension Bill for the Month of February - 2016

SRI VENKATESWARA COLLEGE OF ENGG	Service No :	165
PENNALUR VILLAGE	Bill No :	165
SRIPERUMPUDUR TK	Date of Bill :	27-FEB-16
	Due Date :	06-MAR-16
CHENNAI M G R DT-60210	Tariff App./Bld :	IIB/IIB

Permitted MD : 1089 KVA Transformer Loss : 0 /0. Tr.CAP. 0 KVA

H.T. Bill Working Sheet

Circle code 0411 Service No 165

Power Cut:N LT or HT side :HT side Meter SL NO :TNB66878 Date of Supply:

	Total	Normal	Peak	Off peak
Consumption Summed (Gross(Recorded)egy.consumed)	1,56,024	1,57,404	0	0
Add Computed Cons.	-1,380			
Add Transformer Loss	0			
Reliable Power	0	0	0	0
Less Other Consn	0			
Less Residential Consn	0			
Less Commercial Consn	0			
Nett Industrial Consn	1,56,024	1,56,024	0	
KVAH	1,66,440			
RKVAH	36			
Power Factor	.95			

E & O.E

For DEPUTY FINANCIAL CONTROL

APPENDIX 3

RAW DATA COLLECTION

Campus Load Study - Individual Departments - 15th March 2016

Time Stamp	PSMB 1 & 4			PSMB 2			PSMB 3			PSMB 12			ECE & CIVIL			PSMB 5		
	EEE Dept			MEC Dept			CSE Dept			MR Dept			ECE & CIVIL Dept			MECHANICAL WORKSHOP		
	R Phase	Y Phase	B Phase	R Phase	Y Phase	B Phase	R Phase	Y Phase	B Phase	R Phase	Y Phase	B Phase	R Phase	Y Phase	B Phase	R Phase	Y Phase	B Phase
9:00:00 AM	5.00	12.50	10.00	16.60	5.00	20.00	51.00	47.20	52.00	47.00	75.00	60.00	106.00	49.20	44.70	27.70	25.40	29.00
9:30:00 AM	6.00	27.00	133.00	15.00	0.00	17.00	60.00	44.40	61.60	50.00	88.00	75.00	94.10	47.10	33.10	34.00	31.70	34.00
10:00:00 AM	5.00	45.00	12.00	18.00	0.00	20.00	57.50	47.10	62.60	75.00	150.00	80.00	88.50	46.90	35.50	28.70	26.20	29.50
10:30:00 AM	4.00	15.00	19.00	18.00	0.00	30.00	63.70	48.70	60.20	50.00	140.00	85.00	84.80	28.20	42.60	30.40	28.90	30.40
11:00:00 AM	10.00	20.00	12.00	10.00	0.00	12.00	53.90	49.50	60.40	78.00	135.00	90.00	85.20	23.80	43.40	32.30	30.90	40.00
11:30:00 AM	4.00	25.00	20.00	10.00	0.00	10.00	55.10	43.00	57.60	75.00	140.00	100.00	72.90	44.50	33.50	29.30	26.70	32.20
12:00:00 PM	10.00	26.00	25.00	10.00	0.00	25.00	41.00	31.80	49.20	75.00	150.00	125.00	65.00	24.10	33.30	35.00	33.80	33.90
12:30:00 PM	5.00	38.00	18.00	10.00	0.00	10.00	41.20	31.20	48.20	70.00	150.00	112.00	62.80	32.60	31.90	20.40	29.10	20.00
1:00:00 PM	5.00	25.00	15.00	40.00	0.00	40.00	50.10	40.70	65.80	80.00	160.00	120.00	73.70	57.50	35.90	20.90	17.90	22.40
1:30:00 PM	20.00	40.00	35.00	66.00	5.00	66.00	49.50	52.20	66.80	100.00	145.00	110.00	80.40	54.70	35.90	33.40	29.90	35.40
2:00:00 PM	25.00	50.00	38.00	35.00	0.00	35.00	53.30	41.70	64.90	105.00	125.00	110.00	79.90	50.90	30.20	29.00	21.20	25.60
2:30:00 PM	20.00	50.00	25.00	25.00	0.00	40.00	53.90	46.40	63.30	85.00	120.00	130.00	83.60	49.60	31.50	38.80	35.50	41.00
3:00:00 PM	10.00	20.00	20.00	30.00	0.00	13.00	52.50	45.90	62.00	55.00	120.00	125.00	83.00	50.10	37.50	39.20	36.00	41.90
3:30:00 PM	10.00	50.00	25.00	0.00	0.00	0.00	34.70	31.70	34.30	35.00	75.00	85.00	61.70	16.90	17.10	32.90	31.10	43.20
4:00:00 PM	5.00	37.50	17.50	0.00	0.00	0.00	20.85	20.35	22.05	17.50	37.50	46.25	34.00	8.45	15.90	30.60	29.05	40.85
4:30:00 PM	0.00	25.00	10.00	0.00	0.00	0.00	7.00	9.00	9.80	0.00	0.00	7.50	6.30	0.00	14.70	28.30	27.00	38.50
5:00:00 PM	0.00	17.50	5.00	0.00	0.00	0.00	7.05	9.15	10.00	0.00	0.00	7.50	6.35	0.00	14.90	24.55	23.35	34.75
5:30:00 PM	0.00	10.00	0.00	0.00	0.00	0.00	7.10	9.30	10.20	0.00	0.00	7.50	6.40	0.00	15.10	20.80	19.70	31.00
6:00:00 PM	5.00	10.00	0.00	0.00	0.00	0.00	6.90	9.35	10.15	12.50	0.00	3.75	7.15	0.00	13.00	26.30	24.75	36.40
6:30:00 PM	10.00	10.00	0.00	0.00	0.00	0.00	6.70	9.40	10.10	25.00	0.00	0.00	7.90	0.00	10.90	31.80	29.80	41.80
7:00:00 PM	10.00	10.00	0.00	0.00	0.00	0.00	6.70	9.40	10.10	25.00	0.00	0.00	7.90	0.00	10.90	31.80	29.80	41.80
7:30:00 PM	5.00	5.00	0.00	0.00	0.00	0.00	7.20	9.50	10.35	12.50	0.00	0.00	8.10	0.00	13.65	26.50	24.50	32.55
8:00:00 PM	0.00	0.00	0.00	0.00	0.00	0.00	7.70	9.60	10.60	0.00	0.00	0.00	8.30	0.00	16.40	21.20	19.20	23.30
8:30:00 PM	17.16	46.92	28.06	28.86	0.56	28.07	45.49	40.61	54.50	64.07	101.33	115.33	75.16	45.69	25.59	35.52	31.33	38.96
9:00:00 PM	18.13	49.10	28.76	29.61	0.56	28.61	44.94	40.47	54.00	61.93	95.76	116.18	75.22	46.64	24.24	36.32	31.72	39.94
9:30:00 PM	19.09	51.28	29.46	30.36	0.56	29.15	44.39	40.32	53.50	59.80	90.18	117.02	75.28	47.59	22.89	37.12	32.11	40.92
10:00:00 PM	20.06	53.47	30.16	31.11	0.56	29.68	43.84	40.18	53.00	57.67	84.61	117.86	75.35	48.54	21.54	37.92	32.49	41.91
10:30:00 PM	21.02	55.65	30.86	31.86	0.56	30.22	43.29	40.03	52.50	55.53	79.03	118.70	75.41	49.49	20.19	38.72	32.88	42.89
11:00:00 PM	21.99	57.83	31.56	32.61	0.56	30.76	42.74	39.89	52.00	53.40	73.45	119.55	75.47	50.44	18.84	39.52	33.26	43.87
11:30:00 PM	22.95	60.02	32.26	33.36	0.56	31.30	42.19	39.74	51.50	51.27	67.88	120.39	75.53	51.39	17.49	40.32	33.65	44.85
12:00:00 AM	23.92	62.20	32.96	34.11	0.56	31.84	41.64	39.60	51.00	49.13	62.30	121.23	75.59	52.34	16.14	41.12	34.04	45.83
12:30:00 AM	24.88	64.38	33.66	34.86	0.56	32.38	41.09	39.45	50.50	47.00	56.73	122.07	75.65	53.29	14.79	41.92	34.42	46.81
1:00:00 AM	25.85	45.19	21.83	17.43	0.28	32.92	40.54	39.31	50.00	44.87	51.15	122.92	75.72	54.24	13.44	42.72	34.81	47.80
1:30:00 AM	26.81	26.00	10.00	0.00	0.00	16.46	23.77	24.15	29.90	22.43	25.58	65.21	41.01	27.12	14.07	35.51	30.90	43.15
2:00:00 AM	27.78	18.50	5.00	0.00	0.00	0.00	7.00	9.00	9.80	0.00	0.00	7.50	6.30	0.00	14.70	28.30	27.00	38.50
2:30:00 AM	28.74	11.00	0.00	0.00	0.00	0.00	7.05	9.15	10.00	0.00	0.00	7.50	6.35	0.00	14.90	24.55	23.35	34.75
3:00:00 AM	29.71	10.50	0.00	0.00	0.00	0.00	7.10	9.30	10.20	0.00	0.00	7.50	6.40	0.00	15.10	20.80	19.70	31.00
3:30:00 AM	15.35	10.00	0.00	0.00	0.00	0.00	6.90	9.35	10.15	12.50	0.00	3.75	7.15	0.00	13.00	26.30	24.75	36.40
4:00:00 AM	1.00	10.00	0.00	0.00	0.00	0.00	6.70	9.40	10.10	25.00	0.00	0.00	7.90	0.00	10.90	31.80	29.80	41.80
4:30:00 AM	1.00	5.50	0.00	0.00	0.00	0.00	6.70	9.40	10.10	25.00	0.00	0.00	7.90	0.00	10.90	31.80	29.80	41.80
5:00:00 AM	1.00	1.00	0.00	0.00	0.00	0.00	7.20	9.50	10.35	12.50	0.00	0.00	8.10	0.00	13.65	26.50	24.50	32.55
5:30:00 AM	5.50	66.57	34.36	35.61	0.56	0.00	7.70	9.60	10.60	0.00	0.00	0.00	8.30	0.00	16.40	21.20	19.20	23.30
6:00:00 AM	10.00	68.75	35.06	36.36	0.56	33.46	39.99	39.16	49.50	42.73	45.58	123.76	75.78	55.19	12.09	43.52	35.19	48.78
6:30:00 AM	10.00	70.93	35.76	37.11	0.56	34.00	39.44	39.02	49.00	40.60	40.00	124.60	75.84	56.14	10.74	44.32	35.58	49.76
7:00:00 AM	5.50	73.12	36.46	37.86	0.56	34.54	38.89	38.88	48.50	38.47	34.42	125.44	75.90	57.09	9.39	45.12	35.97	50.74
7:30:00 AM	1.00	75.30	37.16	38.61	0.56	35.08	38.34	38.73	48.00	36.33	28.85	126.28	75.96	58.04	8.04	45.92	36.35	51.72
8:00:00 AM	30.67	77.48	37.86	39.36	0.56	35.62	37.79	38.59	47.50	34.20	23.27	127.13	76.03	58.99	6.69	46.72	36.74	52.71
8:30:00 AM	31.64	79.67	38.56	40.11	0.56	36.16	37.24	38.44	47.00	32.07	17.70	127.97	76.09	59.94	5.34	47.52	37.12	53.69

Time Stamp	PSMB 7 & 7a			PSMB 8			PSMB 10			PSMB 11			Total Energy Consumed (Kw)	LMB 1			LMB 2		
	TOTAL AC's - 500 Tons			CANTEEN			HOSTEL			LIBRARY & ADMIN BLOCK				LIGHTING LOAD 1			LIGHTING LOAD 2		
	R Phase	Y Phase	B Phase	R Phase	Y Phase	B Phase	R Phase	Y Phase	B Phase	R Phase	Y Phase	B Phase		R Phase	Y Phase	B Phase	R Phase	Y Phase	B Phase
9:00:00 AM	60.00	75.00	50.00	8.00	4.50	8.80	20.00	30.00	10.00	2.58	2.14	1.56	208.86	166.67	166.67	133.00	171.90	235.30	179.90
9:30:00 AM	130.00	100.00	70.00	6.20	2.70	5.20	25.00	25.00	8.00	8.88	6.51	13.50	273.56	120.00	125.00	110.00	182.20	237.00	178.40
10:00:00 AM	130.00	100.00	70.00	35.90	31.50	29.00	25.00	45.00	9.00	8.40	5.40	5.72	288.95	125.00	125.00	120.00	193.80	236.80	196.00
10:30:00 AM	80.00	110.00	50.00	10.20	0.00	6.00	25.00	10.00	6.50	7.13	4.69	4.58	238.82	135.00	140.00	130.00	196.30	234.00	173.70
11:00:00 AM	60.00	90.00	40.00	10.30	0.00	5.90	25.00	10.00	10.00	6.90	4.80	4.58	230.27	135.00	140.00	120.00	195.00	231.00	174.00
11:30:00 AM	60.00	50.00	30.00	14.70	4.40	8.80	37.50	15.00	7.00	7.21	4.89	4.53	223.49	140.00	140.00	120.00	209.00	231.50	181.00
12:00:00 PM	90.00	110.00	40.00	34.70	31.50	30.70	9.00	5.00	5.00	7.27	4.73	4.77	254.72	145.00	140.00	125.00	177.50	219.90	180.00
12:30:00 PM	10.00	20.00	20.00	34.90	31.70	30.90	8.00	10.00	5.00	8.63	5.00	4.78	200.87	180.00	160.00	130.00	201.90	215.30	179.40
1:00:00 PM	100.00	110.00	70.00	28.30	29.10	28.70	12.50	14.00	7.00	7.35	4.92	4.82	281.12	180.00	160.00	130.00	201.50	236.30	184.60
1:30:00 PM	100.00	140.00	140.00	28.00	28.80	28.00	10.00	10.00	10.00	5.57	4.38	3.08	334.97	133.00	133.00	120.00	188.60	236.00	162.30
2:00:00 PM	100.00	110.00	80.00	3.30	0.00	4.30	12.00	10.00	10.00	6.30	4.12	3.08	275.92	133.00	135.00	135.00	183.10	237.00	153.40
2:30:00 PM	120.00	135.00	120.00	3.30	0.00	4.30	25.00	25.00	5.00	7.72	4.18	4.60	304.30	160.00	160.00	140.00	179.40	229.00	162.30
3:00:00 PM	125.00	135.00	125.00	3.30	0.00	4.30	30.00	30.00	10.00	7.86	4.15	4.46	288.46	140.00	140.00	150.00	162.20	227.00	167.40
3:30:00 PM	10.00	10.00	10.00	3.30	0.00	4.80	37.50	45.00	10.00	7.17	3.60	3.71	159.22	140.00	140.00	150.00	112.50	171.40	107.30
4:00:00 PM	5.00	5.00	5.00	4.85	0.00	4.35	25.00	35.00	10.00	4.41	2.53	2.38	106.38	120.00	125.00	135.00	76.55	109.35	63.60
4:30:00 PM	0.00	0.00	0.00	6.40	0.00	3.90	12.50	25.00	10.00	1.64	1.46	1.05	53.54	100.00	110.00	120.00	40.60	47.30	19.90
5:00:00 PM	0.00	0.00	0.00	4.85	0.00	3.80	6.25	12.50	5.00	1.30	0.93	1.78	42.94	110.00	55.00	120.00	40.70	42.00	21.55
5:30:00 PM	0.00	0.00	0.00	3.30	0.00	3.70	0.00	0.00	0.00	0.95	0.40	2.50	32.33	120.00	0.00	120.00	40.80	36.70	23.20
6:00:00 PM	0.00	0.00	0.00	4.30	0.00	3.75	12.50	7.50	4.50	0.90	0.20	2.53	44.01	150.00	0.00	150.00	38.51	36.28	34.37
6:30:00 PM	0.00	0.00	0.00	5.30	0.00	3.80	25.00	15.00	9.00	0.84	0.00	2.56	55.14	180.00	0.00	180.00	36.22	35.86	45.54
7:00:00 PM	0.00	0.00	0.00	5.30	0.00	3.80	25.00	15.00	9.00	0.84	0.00	2.56	55.70	180.00	0.00	180.00	36.22	35.86	45.54
7:30:00 PM	0.00	0.00	0.00	6.05	0.00	3.80	12.50	7.50	4.50	0.42	0.00	2.41	41.96	135.00	0.00	135.00	34.61	34.31	43.32
8:00:00 PM	0.00	0.00	0.00	6.80	0.00	3.80	0.00	0.00	0.00	0.00	0.00	2.25	28.22	90.00	0.00	90.00	33.00	32.75	41.10
8:30:00 PM	91.67	101.00	102.33	3.25	3.09	6.61	25.63	34.60	9.20	7.21	3.75	3.71	265.54	146.33	144.73	150.67	143.41	208.19	135.69
9:00:00 PM	94.24	102.82	108.67	0.85	1.37	5.07	26.54	37.73	9.44	7.22	3.61	3.61	267.29	145.92	144.72	154.06	136.56	205.41	130.33
9:30:00 PM	96.82	104.64	115.00	-1.54	-0.35	3.53	27.45	40.85	9.67	7.22	3.48	3.51	269.04	145.51	144.71	157.45	129.71	202.64	124.97
10:00:00 PM	99.39	106.45	121.33	-3.93	-2.06	1.99	28.35	43.98	9.91	7.22	3.35	3.42	270.80	145.10	144.70	160.85	122.86	199.87	119.62
10:30:00 PM	101.97	108.27	127.67	-6.33	-3.78	0.45	29.26	47.11	10.15	7.22	3.22	3.32	272.55	144.68	144.68	164.24	116.02	197.09	114.26
11:00:00 PM	104.55	110.09	134.00	-8.72	-5.50	-1.09	30.16	50.24	10.38	7.23	3.08	3.22	274.30	144.27	144.67	167.64	109.17	194.32	108.90
11:30:00 PM	107.12	111.91	140.33	-11.11	-7.22	-2.63	31.07	53.36	10.62	7.23	2.95	3.13	276.05	143.86	144.66	171.03	102.32	191.55	103.54
12:00:00 AM	109.70	113.73	146.67	-13.51	-8.94	-4.16	31.98	56.49	10.85	7.23	2.82	3.03	277.81	143.45	144.65	174.42	95.47	188.77	98.18
12:30:00 AM	112.27	115.55	153.00	-15.90	-10.66	-5.70	32.88	59.62	11.09	7.24	2.68	2.93	279.56	143.04	144.64	177.82	88.62	186.00	92.82
1:00:00 AM	114.85	117.36	159.33	-18.29	-12.38	-7.24	33.79	62.75	11.33	7.24	2.55	2.83	269.87	142.62	144.62	181.21	81.78	183.23	87.46
1:30:00 AM	57.42	58.68	79.67	-5.95	-6.19	-1.67	23.14	43.87	10.66	4.44	2.01	1.94	159.53	121.31	127.31	150.61	61.19	115.26	53.68
2:00:00 AM	0.00	0.00	0.00	6.40	0.00	3.90	12.50	25.00	10.00	1.64	1.46	1.05	57.10	100.00	110.00	120.00	40.60	47.30	19.90
2:30:00 AM	0.00	0.00	0.00	4.85	0.00	3.80	6.25	12.50	5.00	1.30	0.93	1.78	46.70	110.00	55.00	120.00	40.70	42.00	21.55
3:00:00 AM	0.00	0.00	0.00	3.30	0.00	3.70	0.00	0.00	0.00	0.95	0.40	2.50	38.93	120.00	0.00	120.00	40.80	36.70	23.20
3:30:00 AM	0.00	0.00	0.00	4.30	0.00	3.75	12.50	7.50	4.50	0.90	0.20	2.53	46.27	150.00	0.00	150.00	38.51	36.28	34.37
4:00:00 AM	0.00	0.00	0.00	5.30	0.00	3.80	25.00	15.00	9.00	0.84	0.00	2.56	53.17	180.00	0.00	180.00	36.22	35.86	45.54
4:30:00 AM	0.00	0.00	0.00	5.30	0.00	3.80	25.00	15.00	9.00	0.84	0.00	2.56	52.75	180.00	0.00	180.00	36.22	35.86	45.54
5:00:00 AM	0.00	0.00	0.00	6.05	0.00	3.80	12.50	7.50	4.50	0.42	0.00	2.41	40.21	135.00	0.00	135.00	34.61	34.31	43.32
5:30:00 AM	0.00	0.00	0.00	6.80	0.00	3.80	0.00	0.00	0.00	0.00	0.00	2.25	59.37	90.00	0.00	90.00	33.00	32.75	41.10
6:00:00 AM	117.42	119.18	165.67	-20.69	-14.10	-8.78	34.69	65.87	11.56	7.24	2.42	2.74	279.39	142.21	144.61	184.61	74.93	180.45	82.10
6:30:00 AM	120.00	121.00	172.00	-23.08	-15.82	-10.32	35.60	69.00	11.80	7.24	2.29	2.64	280.94	141.80	144.60	188.00	68.08	177.68	76.74
7:00:00 AM	122.58	122.82	178.33	-25.47	-17.54	-11.86	36.51	72.13	12.04	7.25	2.15	2.54	281.49	141.39	144.59	191.39	61.23	174.91	71.38
7:30:00 AM	125.15	124.64	184.67	-27.87	-19.26	-13.40	37.41	75.25	12.27	7.25	2.02	2.45	282.05	140.98	144.58	194.79	54.38	172.13	66.02
8:00:00 AM	127.73	126.45	191.00	-30.26	-20.98	-14.94	38.32	78.38	12.51	7.25	1.89	2.35	290.08	140.56	144.56	198.18	47.54	169.36	60.66
8:30:00 AM	130.30	128.27	197.33	-32.65	-22.70	-16.48	39.22	81.51	12.75	7.26	1.75	2.25	291.83	140.15	144.55	201.58	40.69	166.59	55.30
													0.00						

TRANSFORMER DATA

Campus Load Study - Distribution Transformers & Controllable Loads - 15th March 2016

Time Stamp	Panel 1			Panel 2			Panel 3			Total
	TRANSFORMER 1			TRANSFORMER 2			TRANSFORMER 3			
	R Phase	Y Phase	B Phase	R Phase	Y Phase	B Phase	R Phase	Y Phase	B Phase	
9:00:00 AM	138.00	173.00	173.00	200.00	30.00	225.00	322.10	338.70	312.10	1911.90
9:30:00 AM	152.00	187.00	172.00	340.00	30.00	325.00	391.00	371.00	337.00	2305.00
10:00:00 AM	169.00	237.00	183.00	210.00	120.00	235.00	394.90	372.00	357.40	2278.30
10:30:00 AM	149.00	205.00	179.00	200.00	120.00	210.00	379.00	330.00	331.60	2103.60
11:00:00 AM	143.00	218.00	175.00	200.00	80.00	200.00	378.00	328.00	337.00	2059.00
11:30:00 AM	130.00	214.00	160.00	220.00	25.00	220.00	375.50	313.90	327.90	1986.30
12:00:00 PM	162.00	244.00	206.00	190.00	10.00	200.00	365.70	321.40	322.30	2021.40
12:30:00 PM	181.00	260.00	235.00	180.00	10.00	180.00	390.50	356.30	352.10	2144.90
1:00:00 PM	206.00	230.00	245.00	200.00	20.00	200.00	385.10	388.00	368.80	2242.90
1:30:00 PM	214.00	235.00	205.00	225.00	25.00	225.00	425.50	421.60	385.10	2361.20
2:00:00 PM	256.00	252.00	240.00	210.00	15.00	215.00	372.60	365.70	318.60	2244.90
2:30:00 PM	220.00	240.00	265.00	230.00	15.00	230.00	390.00	375.30	333.60	2298.90
3:00:00 PM	205.00	227.00	246.00	210.00	20.00	240.00	367.20	372.00	334.00	2221.20
3:30:00 PM	150.00	220.00	166.00	150.00	10.00	150.00	235.30	240.20	205.70	1527.20
4:00:00 PM	98.50	140.00	122.00	125.00	10.00	135.00	159.20	156.50	139.55	1085.75
4:30:00 PM	47.00	60.00	78.00	100.00	10.00	120.00	83.10	72.80	73.40	644.30
5:00:00 PM	40.50	45.00	70.00	110.00	10.00	120.00	74.35	65.35	73.45	608.65
5:30:00 PM	34.00	30.00	62.00	120.00	10.00	120.00	65.60	57.90	73.50	573.00
6:00:00 PM	45.50	15.00	48.00	150.00	15.00	160.00	71.78	68.90	75.65	649.83
6:30:00 PM	57.00	0.00	34.00	180.00	20.00	200.00	77.96	79.90	77.80	726.66
7:00:00 PM	57.00	0.00	34.00	180.00	20.00	200.00	77.96	79.90	77.80	726.66
7:30:00 PM	41.00	9.50	42.00	165.00	20.00	175.00	61.43	69.05	79.70	662.68
8:00:00 PM	25.00	19.00	50.00	150.00	20.00	150.00	44.90	58.20	81.60	598.70
8:30:00 PM	25.00	19.00	50.00	150.00	20.00	150.00	44.90	58.20	81.60	598.70
9:00:00 PM	25.00	19.00	50.00	150.00	20.00	150.00	44.90	58.20	81.60	598.70
9:30:00 PM	25.00	19.00	50.00	150.00	20.00	150.00	44.90	58.20	81.60	598.70
10:00:00 PM	25.00	19.00	50.00	150.00	20.00	150.00	44.90	58.20	81.60	598.70
10:30:00 PM	25.00	19.00	50.00	150.00	20.00	150.00	44.90	58.20	81.60	598.70
11:00:00 PM	25.00	19.00	50.00	150.00	20.00	150.00	44.90	58.20	81.60	598.70
11:30:00 PM	25.00	19.00	50.00	150.00	20.00	150.00	44.90	58.20	81.60	598.70
12:00:00 AM	25.00	19.00	50.00	150.00	20.00	150.00	44.90	58.20	81.60	598.70
12:30:00 AM	25.00	19.00	50.00	150.00	20.00	150.00	44.90	58.20	81.60	598.70
1:00:00 AM	25.00	19.00	50.00	150.00	20.00	150.00	44.90	58.20	81.60	598.70
1:30:00 AM	25.00	19.00	50.00	150.00	20.00	150.00	44.90	58.20	81.60	598.70
2:00:00 AM	25.00	19.00	50.00	150.00	20.00	150.00	44.90	58.20	81.60	598.70
2:30:00 AM	25.00	19.00	50.00	150.00	20.00	150.00	44.90	58.20	81.60	598.70
3:00:00 AM	25.00	19.00	50.00	150.00	20.00	150.00	44.90	58.20	81.60	598.70
3:30:00 AM	25.00	19.00	50.00	150.00	20.00	150.00	44.90	58.20	81.60	598.70
4:00:00 AM	25.00	19.00	50.00	150.00	20.00	150.00	44.90	58.20	81.60	598.70
4:30:00 AM	25.00	19.00	50.00	150.00	20.00	150.00	44.90	58.20	81.60	598.70
5:00:00 AM	25.00	19.00	50.00	150.00	20.00	150.00	44.90	58.20	81.60	598.70
5:30:00 AM	25.00	19.00	50.00	150.00	20.00	150.00	44.90	58.20	81.60	598.70
6:00:00 AM	25.00	19.00	50.00	150.00	20.00	150.00	44.90	58.20	81.60	598.70
6:30:00 AM	25.00	19.00	50.00	150.00	20.00	150.00	44.90	58.20	81.60	598.70
7:00:00 AM	25.00	19.00	50.00	150.00	20.00	150.00	44.90	58.20	81.60	598.70
7:30:00 AM	25.00	19.00	50.00	150.00	20.00	150.00	44.90	58.20	81.60	598.70
8:00:00 AM	25.00	19.00	50.00	150.00	20.00	150.00	44.90	58.20	81.60	598.70
8:30:00 AM	25.00	19.00	50.00	150.00	20.00	150.00	44.90	58.20	81.60	598.70

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