OPTIMAL COMMUNAL DEMAND RESPONSE PROGRAM USING BATTLE ROYALE OPTIMIZATION ALGORITHM

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Certificate

We accept the work contained in this report as a confirmation to the required standard for the partial fulfillment of the degree of MS (EE).

Head of Department

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Dedication

This thesis is dedicated to my parents and teachers for their endless love, support and encouragement.

Declaration of Authorship

I, **NADEEM KHAN** Registration no **01-244191-015,** hereby declare that the presented work in this thesis is my own. To the best of my knowledge, it does not contain any material that is published previously or written by any other person, I have not taken any material from any source except referred to wherever due that amount of plagiarism is within acceptable range. If a violation of HEC rules on research has occurred in this thesis, I shall be liable to punishment action under the plagiarism rules of HEC.

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Abstract

Presently, power distribution structure depends on conventional design of power grid and deployment which is not fulfilling the energy requirement of the 21st century. As the electrical system is shifting from conventional power system to smart grid system there is more need of developing demand response methods that meets power generation and demand in more efficient way. This study is about analyzing and identifying the decreased power cost by overseeing demand response in terms of consumer appliances and changing of power consumption in peak hours and off-peak hours.

There are many strategies that provide monitoring control over the consumption of power and loads with the purpose of cost reduction in the utility bills. The implementation of the advanced technology inside grids, in the transmission systems, generation and distribution of power, is providing solutions of power consumption problems. This leads to the expansion of energy demand worldwide. Loads addition and more power consumption is one of the significant issues that deter the energy efficiency and performance of smart grid systems. So far, the power demand is vesting huge percent of electrical energy consumption. Therefore, demand side load systems known as home energy management systems (HEMS) at communal level, are being executed under the new smart grid idea. The observation of the results of home energy load systems is generated by the distinctive load profiles showing different parameters including, appliances power utilization, environment protection, number of consumers in community and types of appliances that are being used in residential area.

This research intends to give a better solution to minimize cost of power and user comfort by observation and assessment of demand side load based on a novel Battle Royale Optimization Algorithm (BROA). In BROA, loads are considered as soldiers, comparison of soldiers and finally the best soldier is opted as elite among the total number of soldiers at the termination level.

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ABBREVIATIONS

BROA	BETTLE ROYAL OPTIMIZATION ALGORITHM
DLC	DIRECT LOAD CONTROL
DR	DEMAND RESPONSE
DSLM	DMAND SIDE LOAD MANAGEMENT
DSM	DEMAND SIDE LOAD
EE	ENERGY EFFIENCIENCY
GUI	GRPHICAL USER INTERFACE
IOT	INTERNET OF THINGS
LP	LINEAR PROGRAMMING
LS	LOAD SHIFTING
RE	RENEWABLE ENERGY
TOU	IME OF USE

Chapter 1

Introduction

CHAPTER 1 INTRODUCTION

1.1 Overview

Smart Grid is the revolution in the field of electrical power system and known as next generation power system grid featured with duplex communication of electrical signals. It has resilient distribution system of power to the end-user of electricity. Power system automation, load profiling, scheduling of loads, controlling emission and all kind of information about the appliances to the consumer are the characteristics of Smart Grid. Before Smart grid, problems of power generation, distribution and demand of power were common to the power utility providers and for the consumers. But, after the smart grid deployment in power system, an intelligent electrical power system is emanated with solutions of the problems of conventional power system.

In this regard, Demand Side Management (DSM) is unprecedented in smart grid system for the effective management of energy with the objectives of reducing cost of power. On the other hand, the consumer demand includes; residential, industrial or corporate/business are fulfilled by applying DSM techniques and methods. The course of action of consumer's association with grid station arranged by accessible supply and cost. In addition, demand side load is the execution of those techniques to lessen cost and optimum utilization of power supply [1].

There are two classifications of DSM, energy efficiency (EE) and demand response (DR). EE strategy is fundamentally utilized for power saving. For this reason, the consumer utilizes the appliances which are power effective. Energy efficiency method is also sometimes referred to as energy preservation. DR is likewise utilized for the diminishing expense of energy. There are various sorts of DR techniques to decrease cost of energy such as, load shifting, direct load control and time of utilization. In load shifting strategy, the load is shifting from peak hours to off peak hours.

For load shifting strategy, the consumers utilize two techniques, shifting of load through programmed way and shifting of load through indirect strategy. In direct load control technique, the service provider saves energy to control the load, for this reason the buyer turns off some loads temporarily. The third strategy is time of utilization in which the consumers distribute various slots of time for energy use. Various slots of power use convey distinctive scope of power cost. Moreover, Time of Use (ToU) method provides comfort to consumer that energy consumption in off-peak hours rather than peak hours. To time-based rates of power, the DR give a chance to buyers to devour energy in off peak hours. Technique for drawing in consumers with demand response. In DR strategy, the provider can handle the supply of power straightforwardly controller switch.

Load shifting (LS) is a method to utilize the energy by shifting some load from peak hours to off peak hours without roll out any improvement in the measure of consumed energy. LS shows an electrical potential for decreasing the peak loads in the plan. LS relies upon revising of smart home management from peak hours to off peak hours. LS intends to move power consumption from peak hour to off peak hour by delaying initial ON states of loads with one time then onto the next. The primary reason for load shifting is to save cost of energy.

The Time of-use (TOU) methodology gives optimal power to consumer at certain times in 24 hours when the demand of power is at lowest level while the cost of power is not. TOU has two advantages for consumers that they can lessen their cost and deal with their demand. TOU gives that cost of power ought to be high when the demand of power at high point and vice versa.

Energy effectiveness is likewise another strategy of DSM through which a customer can lessen energy consumption by changing their typical appliances by energy efficient appliances. Through the installation of energy efficient appliances rather than traditional appliances, a consumer can reduce the utility bills. The life of energy efficient appliances is increased because the power rating of energy efficient appliances is significantly lower than non-energy efficient appliances for the home usage. For example, the LED lights consume less energy than filament bulbs.

1.2 Problem Statement

Recently, both electric utilities and consumers have encountered the expanding costs of electric power and energy due to growing expenses of energy cost. In this regard, Load management (LM) is used to change the states of the loads in peak generation hours or restricted the loads addition with main grid. LM applications in the industrial areas have been restricted likely because of absence of information about controllability of loads and varieties in the demand example of various loads.

Demand side is the side that demands for electrical energy. DSM is the execution of those estimations that help the buyers to lessen energy consumption and cost. There have been various strategies and models presented for ideal energy consumption through load management without bargaining Consumer comfort. For a similar explanation, this work proposes another method dependent on Battle Royale Optimization that can conceivably give a straightforward and quickly implementable answer for the load management in private, business and industrial zones.

1.3 Objectives

The overall objective of this work is scheduling the loads for reducing the energy price. General categorization of loads will be used for the implementation of BROA. For this reason, the following milestones were set and achieved in this work:

i. To minimize the electricity cost.
ii. Maximize user comfort.
iii. Scheduling of all categorizations of appliances using BRO algorithm.
iv. To use BRO procedure to estimate energy consumption and managing them.

1.4 Battle Royale Optimization Algorithm (BROA)

There are many optimization techniques which have been exhorted by the researcher recently for the analysis of power system. The most prominent and effective techniques devised so far include Energy Efficiency, Demand response, Spinning Reverse and Virtual Power Plants.

BRO is a novel optimization procedure based on game strategy. This algorithm is based on battle Royale video games. BRO is one of the other existing swarm-based technique, it is also based on population. To achieve the optimal solution BRO utilizes a population candidate solution. Each solution of them is known as a soldier who tries against its closest neighbor to defeat. Thus, a solder can defeat other solder if he is located in a suitable place. Therefore, all soldiers are trying to take a suitable position to have more chances to take away themselves from death. At the end the winner solder is best one. The appliances being switched during the simulation are considered as the soldiers whereas other parameters are also linked likewise which are explained later.

1.5 Load Profile

Loads can be grouped dependently on different variables. Various definitions are made with respect to the arrangement of loads in the writing. A few investigations partition the loads into two classifications as shift able loads and non-shift able loads. While shift able loads are exceptionally identified with the living propensities for individuals living in the houses, non-shift able loads are profoundly reliant on environment conditions.[2]

A couple of examinations organize the private loads as shown by their necessities. For instance, lights, TV, and coolers can't be yielded to later periods. Henceforth, these sorts of loads are considered as principle objective loads. Loads using warm limit, for instance, water radiators, and environment control system can be surrendered to not all that inaccessible future periods and they are considered as second need loads. Other loads, for instance, dishwashers, and articles of clothing washers can be surrendered to various periods and an enormous bit of purchasers need not to mess with them up in a brief period. Subsequently, these sorts of loads are termed as third need loads. Demand of electrical apparatuses and relating models is shown in the Figure 1.1. Other demand of private loads relies upon apparatuses' assessed power utilization. This demand is on a very basic level divided into light loads (1000 W).

As referenced above, the load arrangement is a significant factor which influences DSM advancement. For the investigation viable, the load profile utilized in the work is of five kinds. These loads are classified based on their activity time and need for certain ecological elements included also. Every one of these loads has its own booking needs which shift in like manner with the previously mentioned boundaries. The detail of the load profile utilized in this examination is clarified in Chapter 4.

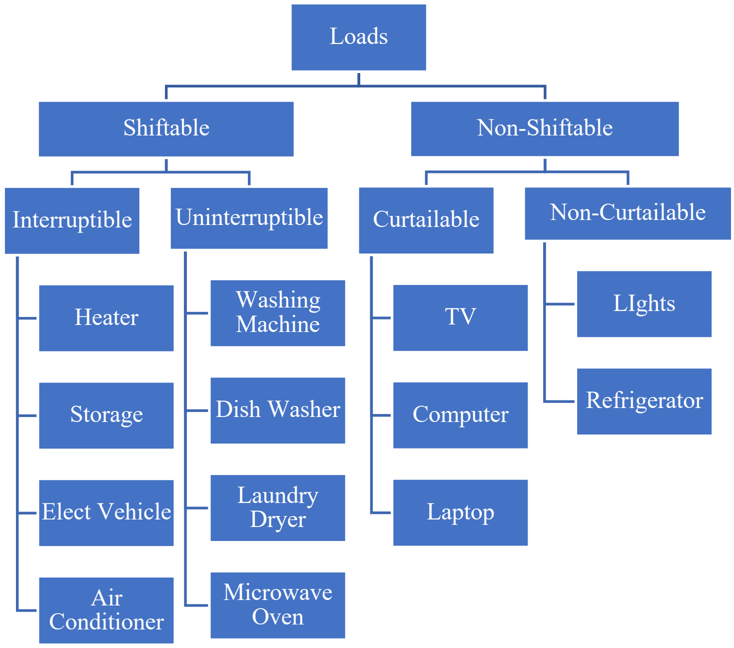

Figure 1.1: Electrical Appliances Classification

1.6 Electricity Cost Variation

To fulfill the object of the effective management of the resources and the generated power, one should consider the variations in the cost of electricity consumption. This is possible with a proper system which control and limit the cost of utilization of the energy based on the applications and requirements. [3]

As a significant proportion of demand response, the interruptible load can be comparable to a virtual generation unit, which assuages the pressure of power supply in peak hour and reduces the frequency of start-up and closure for the peak shaving unit. To maintain a prominent distance from irregular characteristics endangering system steadiness activities to present new energy supply and demand response advances are taken. In nuts and bolts, demand response control thought is a decision, how profound consumers will permit coordinate his home appliances in load adjusting and that degree of conceivable discomfort will be traded for benefits. Each smart appliance has provision of settings. For instance, coolers might have provision of temperature set control. Present day refrigerators are very much protected and can keep cold in a cooler as long as 6 hours with no food harm. Order from "Aggregator" as indicated by a permitted level of effect will actuate significant (higher) set temperature for a fitting time. Key component of such control is data conveyance to all appliances. Establishment of dedicated connection by the power provider can be incredibly expensive, so correspondence by means of power avarice ought to be thought of.

DSM can change the energy use mode to shape the load, to achieve peak load shifting, improve power supply adequacy, encourage the force need pressing factor and decline the cost. Due to the high load operation during peak periods, power supply association uses the fundamental techniques for DSM "peak load shifting", explicitly as demonstrated by load characteristics, through definitive, specific, financial and individual expects to misleadingly change immense customer associations working or working plans to dodge the load peak, thusly, decreasing the difference among pinnacle and low of energy load, upgrading resource partition and improving the security and economy of the system.

Chapter 2

Literature Review

CHAPTER 2 LITERATURE REVIEW

2.1 Background

Generally, electric power systems have experienced more loads because of growing power demand, excessive use of power and losses of power during generation and transmission. Transmission line blackouts have been a typical reason for system load conditions, which are conceivable to happen during peak hours. Such occasions will cause a supply limit circumstance where power consumption is at higher rates. Arising difficulties, for example, growing system, ascend in demand, high power rating appliances, and expanding fossil fuel byproduct are driving consumers and power service provider from power grid towards smart grid. Because of this leap of innovation, the load of appliances at private and industrial zones separately can get simpler than previously.

There have been a few methodologies recommended in numerous papers to clarify the issue of energy management. Home energy management methodology is addressed by linear programming (LP), which is proposed in [4]. This is an important technique to showdown the load which guarantees the ideal outcome. HEMS (Home Energy Management system) dependent on streamlining through liner computer programs is proposed in[5]to decrease the general consumption. This work considers, Consumer alleviation is additionally considered by restricting the device in a limited time frame. It is computationally acceptable however cost versatility isn't considered into account. A system which is numerically improved dependent on demand side load model is introduced in [6]to join the RE inception with the grid energy. In term of reaping and cost of RE crafted by this system is effectively, while the expense still computationally troublesome. [7] talked about a blended whole number LP is used for booking numerous types of devices to diminish the buyer's power cost. The issue in the strategy is additionally numerically troublesome and computational multifaceted nature.

Ideal halting guideline in [8] has been used, which is another numerical strategy for booking the appliances. In this system the appliance holding up times are likewise shown as an expense modular. In this system the healthy strategy of skirt, where all appliances share their power use plan with power regulator on this way ascertains, makes a move and limit. It is an effective and assorted system, so for huge scope grid it is not able to expand the quantity of appliances which will build the execution overhead of regulator to figure the edge.

In [9]-[10], high importance has been given to basic load gadget engaged by utilizing the load prioritization strategy. Appliances are assigned distinctive huge conditions and boundaries as needs be. Energy load makes a move on this premise. In [11] based on double disintegration methodology a social government assistance amplification (SWM) strategy is proposed. Shopper and utility both get advantage by improving the all-out expense and alleviation of the Consumer. An element of appliances sitting tight time is utilized for purchaser's thwarting and is demonstrated utilizing disutility work, which shows that if the shopper utilizes a lot of energy, its alleviation can be decline or expanded when measure of energy utilized is decrease from a hankering limit.

In [12], the authors coordinated the devices to improve the purchaser help. The inclination of temperature, the indoor regulator is coordinated by a coordinator appropriately to the structure temperature, which is supported with most minimal redirection. To diminish peak normal proportion, a game hypothetical model is recommended in [13]. Which works in neighborhood geography and each customer thought to be a player to play in a game to finding the ideal estimation of the advancement task. Besides, in [14], specialist proposed a model for purchaser to utilize the device to give help in term of power. Also, a strategy is proposed in [15], in which customer change the appliance time to recognize the resistance. By considering this resistance the vital objective of this strategy is to diminish the expense of power. In [16], purchaser ease alert HVAC (Heating ventilating and cooling) plot is recommended. It is thinking about the customer heating subjects and capacity, the modular of HVAC thermodynamic is addressing the streamlining task by utilizing nonlinear strategy and control the home temperature. In [17]-[18], the component of energy protection is used in which shopper help is considered by observing the appliance indoor regulators likewise, the tendencies of temperature by buyer. In these sorts of energy effective technique, the purchaser presence and tendency should be considered. The consideration of the insight in indoor regulator, which achieves the efficiency of energy.

In[19], the scientist introduced another ML (AI) strategy which protects energy by adding insight in programmable correspondence indoor regulator. For the everyday energy consumption, the Consumer design is gotten the hang of utilizing remote sensor organizations and moves are made based on day-by-day energy consumption. Some of the priory used strategies and techniques are covered in this chapter in order to develop a deep understanding of the work conducted under this research.

2.2 Demand Side Management by Maximum Power Limited Load Shedding Algorithm

In [20], the work of energy limited load shedding calculation for DSM applications in local scales is inspected. By using this calculation, local energy utilization is confined with respect to dynamic energy esteem signal and harmless to the ecosystem power age level by turning off the low prior home equipment machines (HEAs).

The assessment improves the best energy confined load shedding calculation to consolidate shift mode control dependent upon second local RE age potential. In the investigation, the effect of local RE age on DSLM reliant on load shedding were numerically analyzed. Propagation results unquestionably show that RE age can lessen proportion of load shedding and abatement misery of customer coming about due to turning off apparatus. Furthermore, the proliferation results insist that matrix energy dependence of home decreasing depending upon RE age capability. It was in this manner deduced that DSLM and local RE age supports each other and they can business related to diminish system energy use and energy utilizations of homes in future keen lattices applying on the web power assessing demand.

2.3 Optimization Mode for Industrial Load

In [21], a physically based model and definition for modern load was introduced. The plan uses number straight programming strategy for limiting the power costs by planning the loads fulfilling the cycle, stockpiling and creation imperatives. The proposed methodology is assessed by a contextual analysis for an average flour plant with various load alternatives. The outcomes show that huge decreases in peak power consumption are conceivable under time of utilization levies. The model proposed in the paper is based at the hardware level in continuation to the actual models. It incorporates the time subordinate use and effectiveness boundaries of the machines or gadgets of the cycle and thinks about the capacity, cycle, stream and creation limitations. The model is combined with an enhancement system to endorse ILM methodologies.

The proposed model was fit for examining the business response to various taxes, operational methodologies like a few move activity, variety of hardware size or capacity limit and selection of new innovations. The contextual investigation for a common flour plant led in a similar examination shows a chance of decrease of system peak incidental power consumption by 95% of the current worth. Ideal working procedure of the plant brings about complete expense saving of 29%.

2.4 Demand Side Management of a Renewable Energy Zone

In [22], a Renewable energy power park was taken as a subject and demand side load the load's methodology was executed to research the results. The Park is a Micro grid, an energy dispersion structure that can manage itself and gain power from economical energy sources and from the energy lattice additionally. In any case, the assessment of the available energy load and supply data of the Park are presented in this work. The synchronicity of the load and supply, furthermore the possibility of the Park for essentially islanded mode were settled during the figuring. The important task of the work was to separate how the interest side administration can maintain the presence of the islanded action. Finally, a proposition for the augmentation of the maintainable energy limit was made.

The aftereffects of the work uncover that, with the assistance of the demand-side load there is an opportunity for expanding the virtual islanded mode proportion. Nonetheless, this would change the devouring conventions of the Consumers, which can adversely affect the parts of accommodation. Accordingly, the inquiry may emerge, is it worth to it to make such a penance from the side of the Consumers or from the power provider. For the appropriate response more profound explores are required, which can raise data about the impact of the DSM on the purchasers' regular daily existence, on the specialized activity of the system, or even on the monetary side of the entire arrangement. Moreover, to accomplish an all-out islanded mode activity critical over sizing would be needed in the introduced power and capacity limits.

2.5 IoT based Demand Side Management

In [23], the creator sets up a load system for energy assets in miniature grids to progressively extemporize the current approach for energy consumption and load by methods for utilizing more environmentally friendly power sources and giving a financially savvy system. With the assistance of IoT mists, information stockpiling has been conceivable and better observing has likewise been set up. Here, the IoT stage UBIDOTS is utilized to make information open anyplace across the world to the individuals who have the correct certifications. Our arrangement comprises of two arrangements of three micro grids to portray the load of energy among various miniature grids. The power (kwh) values are entered through potentiometers with the goal that the varieties can be communicated in voltage at various focuses in time (continuous recreation) into our system. The essential information is the demand side load and different data sources are the ecological factors (sun based and wind power creation esteems, and battery limit esteem). These qualities are then controlled by building algorithms for demand side load and load sharing. The yields are introduced as LEDs which address the energy asset utilized in agreement to the rationales performed. Subsequently unique energy load has been conceivable. By looking at the pattern in demand side load, a different relapse model has been made to notice and successfully make changes to the system that can additionally improve its capacity. The whole model of the proposed system is truly executed utilizing Arduino and IoT modules with earlier outcome examination in MATLAB.

The paper infers that arrangement of demand side load utilizing an Arduino microcontroller, MATLAB and IoT stage can be broadly utilized by enterprises. All the miniature grids or hubs can be controlled and observed by the administrator and every hub can be used by singular Consumers. Consequently, the entire system utilizing the Internet of Things encourages the control of the system distantly from anyplace on the planet. This system isn't just practical however can likewise be extended according to need and demand without any problem. Additionally, the appropriation of AI into our system utilizing MATLAB can be very useful in anticipating the ideal yields and continually refreshing the system by mulling over the ever-changing demand.

2.6 High-Power Load for Residential House

In [24]. To keep a comfort level of living under this dry climatic condition, Residential houses ought to be outfitted with essential workplaces and high-power home machines, for instance, Air-Conditioners, water radiators, refrigerators, pool siphons, laundries, and so forth Moreover, power cost could be very surprising at peak time and non-peak time as the day advanced. Similarly, by arranging impediment gauges, the comfort level of housing indoor temperature is guaranteed, and energy utilization maximum cutoff is kept. Finally, the improvement control plot is affirmed through a circumstance under typical periodic environment conditions. The results show that the most negligible cost of energy utilization can be refined by the proposed improvement control of house load the loads.

The results obtained from the work under this assessment reflect that to achieve a cost zeroed in on load the loads for private house under Qatar desert environment conditions, an upgrade and control plan of load utilization for close by private house proposed in the paper is significantly amazing. By arranging constraint estimates pondering close by environment impacts, the base cost of complete energy can be refined with a comfort level of housing living while most of the incredible load are sorted out some way to work in a profitable way. Reenactment results show that the proposed improvement control plot is affirmed under average periodic environment conditions. Future work will be driven on more obfuscated circumstances with nuclear family PV age and limit.

Chapter 3

Demand Side Management

CHAPTER 3 DEMAND SIDE MANAGEMENT

3.1 Overview

With demand side, energy sources can be utilized all the more effectively as the demand side can be compelled to follow the generation accordingly. Two principal approaches in demand side load systems are given as motivating energy-based on the systems and cost of the system. In the motivation-based systems, Consumers are offered a few advantages as a trade-off to tolerating certain conditions forced by the utility. In the cost-based systems, Consumers can effectively take an interest in demand response dependent on the value data. Continuous data trade-off between the Consumer side and the utility side is the critical factor for these systems.

The energy consumed by residential and private sector is one of the huge issues for energy efficiency and future smart systems since these sectors comprise of a huge percentage of total energy consumption all around the globe. Thusly, demand side management systems, named as home energy the loads' management at the private level, are being executed under the new smart systems architectures. Home energy management systems are getting progressively more common with extending number of smart home appliances.

DSM can be gathered into two segments. The first is "energy efficiency" (EE). In this strategy, the primary concern is to save power. To do thusly, we ought to use energy efficient machines. Energy security can likewise be considered as a piece of energy efficiency technique. Second one is "demand response" (DR). Demand response can be secluded into; time of use, direct load control and load shifting. In time of use strategy, consumers are apportioned particular time period to use power. Unique time plans give different prizing range. This urges customer to use energy in a moderate way and license provider to manage the record. Because of direct load control, load can be indebted by the suppliers. A couple of loads are cut off for a confined period to save energy. The last one is load shifting. It is the route toward shifting load from peak hours to off-peak hours. Load shifting is of two sorts: indirect load shifting and direct load shifting. Figure 3.1 shows how DSM can be described.

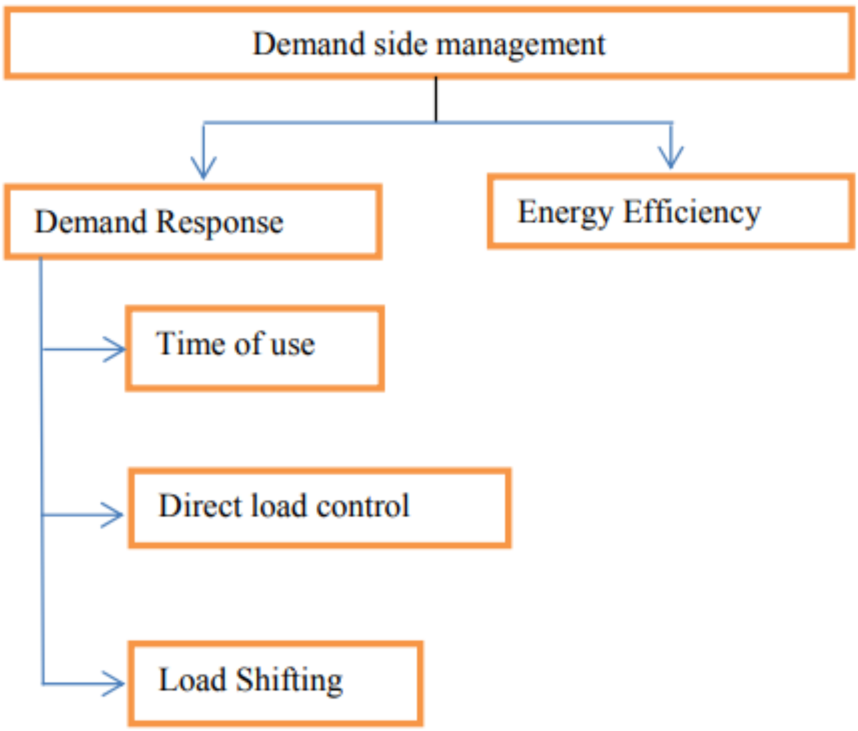

Figure 3.1: Demand Side Load General Classification

3.2 Demand Response

Demand response suggests strongly decreasing concentration. No change is done on the consumer's side. Demand Response is certainly increasing more profit for the market and for the energy system. Shifting energy from peak hours to off-peak hours and in this way scatter the load is one way to deal the interest side. These pinnacles are both extreme to manage and a risk to the climate since marginal creation advances can be overpriced and are commonly fossil based. Shifting/diminishing energy ought to be conceivable by demand response and there are a ton of customers taking an interest program consequently. A couple of features of DR: market driven, customer controlled and punishment for hindrance offer purchasers an opportunity to acquire money in energy market.

3.3 Time of Use (ToU)

As opposed to a singular level rate for energy use, variable expense is given in this technique. Time of-use (TOU) esteeming is a variable rate structure that charges for electrical energy depending upon the hour of day and the season the energy is used. With season of-use rates, bill will be constrained by both when energy is used and what sum is used. In California USA, summer has three rate-periods: off-peak, half peak and peak. Winter has two rate periods: off-peak and half peak. Season of-usage rate plans at all various occasions will be lower than the peak rate. Right when the interest is higher, the expense of energy should be high and when demand is minimal, power should be low.

3.4 Direct Load Control

In direct Load control strategy supplier can deal with the standard of energy clearly. During the preferred hour if any purchaser uses more than a particular proportion of energy the supplier can confine that buyer's utilization. For example, if the suppliers' course of action is repetition of sensitive hand-off and a controller with every affiliation which will open the hand-off after a particular amount of energy is consumed by the controller in preferred hour, it will fulfill the explanation behind direct load control. Not all the devices are optimum for direct load control. Devices like refrigeration load, warming and cooling contraptions are sensible for this. Most prominent impedance time can be from 30 minutes to 1 hour and it will in general be applied for 2-3 times each day. The impact should be little with the ultimate objective that it should not be seen by the customers [25].

3.5 Load Shifting

Load shifting is such a cycle where the load is moved, and it doesn't reveal any improvement in the proportion of consumed energy. Demand Side Load programs using load shifting strategies show extraordinary potential for diminishing the peak loads in the suggested demand plan. The fact is to construct the efficiency of the system via conveying both demand and supply to the best low worth.

Peak period ordinarily incorporates more extreme expense of energy than that during off-peak. In this way, customers can put aside money by shifting load from peak period to off-peak period. Asking buyers to move their load is done by engaging purchasers or executing electronic advising organization that reminds customers about load shifting.

3.6 Load Management Techniques

The power supply and demand planning are essentially insinuated as manage the load. Manage the load programs save the interest for power in balance with the available inventory. Manage the loads and DR can be considered as not simply a response for the techno-money related issues of an energy market yet also a socially careful plan. The purpose of the manage the load systems is to diminish peak demand. There is a huge qualification between manage the load and energy protection. While manage the loads techniques are wanted to reduce or shifting interest from peak hours to off-peak hours, safeguarding methodologies are intended to diminish usage over the entire 24-hour load period. Manage the load isn't ordinarily an energy saving application, it anyway is used to run the energy structure even more capably. While, energy is ordinarily not being saved with manage the loads, load demand is moved to off peak hours. Three essentials manage the load techniques are used to level the peak demand. These are load shifting, peak cutting and valley filling. Load shifting is the sort of manage the load and it targets decreasing customer interest during the peak time-slots by shifting the usage of appliances from peak pours to off peak hours. In load shifting, loads are not being turned off, not in the slightest degree like peak cutting, where loads are partially or completely shut down. The full-scale utilization has no impact in load shifting.

Chapter 4

Methodology

CHAPTER 4 METHODOLOGY

In order to implement the proposed system, a framework based on Battle Royale Optimization algorithm was implemented. The entire setup was prepared and tested in a simulation. The Battle Royale Optimization was implemented using the code which takes several inputs and generates the requisite switching sequence for the loads. In order to implement all the aforesaid scenario, the loads were categorized accordingly, and their profile was adjusted using the same approach. The entire methodology of implementation and designing is covered in this chapter.

4.1 Load Categorization

The simulation was tested using a scenario where a standard house is taken and the appliances inside of it are considered as loads. The loads consist of several appliances such as television, Air Conditioner, refrigerator etc. All of these loads have their own priorities and running time which was taken as a key parameter to categorize all loads. According to the designed system, these loads were placed under five categories as under:

Type 1 Loads: *Scheduled*
Type 2 Loads: *Permanent*
Type 3 Loads: *Semi-Permanent*
Type 4 Loads: *Occasional*
Type 5 Loads: *Circumstantial*

In the above categories, Type 1 loads (Scheduled) are referred to the types of load that are active for a specified period during 24-hours irrespective of the environment or other parameters under normal and standard conditions. A major example of such kind of loads is lights. Lights are commonly turned on when it is dark. However, the circumstances may vary but there are several areas inside a residence where the lights are only required during the night.

The Type 2 loads (permanent) are the loads that are turned on 24-hours irrespective of the climate or weather conditions. These types of loads include security systems and lock controls. Such kind of loads tend to remain on all the time unless there is an unforeseen situation such as maintenance etc.

Type 3 loads (semi-permanent) are loads like refrigerator. Even though such loads remain on all the time but the outside temperature, humidity and other environmental factors may affect the operating time. This means that such loads can be switched off for a small duration if the weather and environmental conditions are feasible.

Type 4 loads (Occasional) do not have any specific on or off time and are not necessarily required. Such kind of loads are the primary target whenever the load is excessive. Even though the power consumption of such loads compared to other bulky loads is negligible but with multiple loads, when the residence is bigger and contains much more similar kind of loads, the load on the grid can be reduced extensively.

The last loads are the Type 5 loads (Circumstantial). The operating time of these loads vary excessively with weather conditions and in most of the cases, such loads consume a lot of power. The appliances categorized under such loads contain Air conditioners, fans, electric heater etc. Some examples of each type of loads are shown in the Table 4.1.

Table 4.1: Appliances and load type

Category	Nature of Loads	Loads
Type 1	Schedule	Washing Machine, Dryer, Heater, AC, Electric Vehicles, Computers
Type 2	Permanent	Security Cameras, Surveillance System
Type 3	Semi-Permanent	Refrigerator, UPS, WIFI Device
Type 4	Occasional	Decoration Lamps, Party Lights, Sound System
Type 5	Circumstantial	Iron, Microwave Oven, Electric Rods

4.2 Battle Royale Optimization

The implementation of BRO under the defined circumstances was a challenging task as each parameter cannot fit the situation precisely. The BRO technique defined earlier was thus tailored according to the provided conditions in order to get better results.[26]

Battle Royale Optimization algorithm is inspired by the battle Royale games. Large number of players are added in battle, where everyone fights with others. In team-up mode, every team tries to defeat all other teams one by one and ultimately an elite soldier or elite team is the winner of game. After the passage of time, the battle area is reduced from larger to smaller and so on. The new area after contraction is considered as safe, all must remain in safe area for survival and to remaining in game. Initially, all the players and teams are located at random locations and to seek the other players and teams for shooting. If a player is injured then the index of damage of player is increased and will be recovered when the same player kills or damage the other players. Further, the revivals of players are possible in some battle Royale games. After the death the player is returned to battle on other random location. There are many battle Royale games but the most prominent are PUBG, Counter Strike, Free Fire and Call of Duty.

Battle Royale Optimization algorithms is started by the initiation of position of soldiers in the space field and the other parameters of the algorithm such as threshold, damage and victory indices. After the initialization, next step is the comparison of soldiers, for instance first soldier is compare with the second and then third and so on till the last soldier of the space. Comparison is based upon the damage and victory status of the soldier. If one is injured by any other soldier then its value of damage will be increased by one and it will be recovered only by the injuring other soldiers. In the same manner, if a soldier hits other, then victory values will be raised.

After updating the values of damages and victories of entire force in the battle. The damage is assessed with the threshold constant value. If the value is below the threshold then it relocates the soldier with new value and damage index of that soldier is increased. In false case, soldier is relocated and its damage and victory value are reset by assigning the zeros. Above threshold or equal threshold means that soldier is dead and need to alive and need to return to the battle again by assigning new random location. After this assessment, the location of the all the soldiers is updated and battle is contracted for the soldiers. New area of arena will be smaller than the previous areas and it shrinks again after allotted time. Next step is the evaluation of termination criteria, which decides the best soldier or to restart the whole process again by comparison. If criteria of termination are fulfilled then the best soldier will be opted as elite and algorithm will be terminated otherwise the condition of comparison will start again for searching the best soldier. In figure 4.1, the holistic view of the BRO is illustrated for better understating.

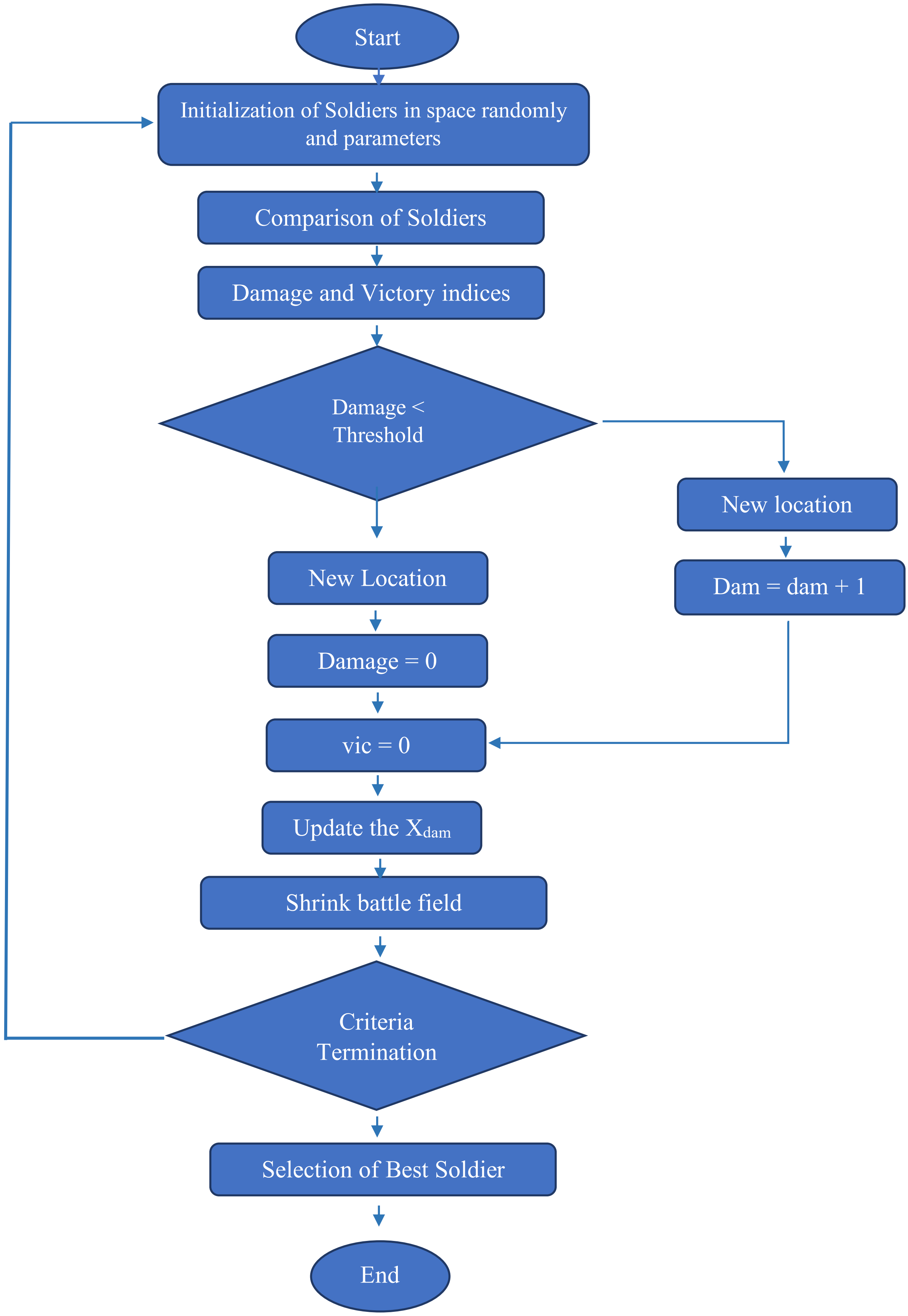

Figure 4.1: Flow chart of BROA

In this regard, the residence, which in this case was a standard house, was taken as the problem space. The appliances (Loads) were considered as soldiers which fight against each other and those with the most favorable conditions tend to have an edge over the other soldiers or appliances.

The input parameters taken into account are the peak hours, time of the day (Day or Night) and outside temperature. These three parameters were adjusted to get the output as a normal sunny day. The temperature and day/night parameters are uniform whereas the peak-hour data was assumed in accordance with the time. It is worth mentioning that in order to analyze the system under different climate conditions, the parameters can be set accordingly.

The time of the day was categorized as day or night which makes two possible conditions. The temperature and peak-hours were accordingly categorized into three possible conditions i.e low, medium and high in order to avoid complexity. The system also has a provision to introduce multiple levels of these parameters in order to get more accurate and precise optimization. The peak hours are high during the office hours, but distribution is non-uniform unlike the temperature. Figure 4.1 shows the transition of these parameters.

Aside from this, the system also has several other conditions to make the output and switching more in line with the objective of the research. One of these conditions include overall power consumption. Thus, when the system exceeds a certain defined level of power which is being drawn from the source, it automatically switches off loads that low priority which makes the system more efficient. The set power for this purpose in the simulation is 6000 Watts or 6 KW.

Besides, two other important conditions were also taken into account while designing the system. These conditions include the "off" time of semi-permanent loads and "on" time of circumstantial loads. The conditions were set in such a way that the semi-permanent loads cannot be switched off for more than three hours whereas the occasional loads cannot remain on for more than 02 hours. The loads constantly monitor these parameters and conditions and whichever scenario becomes dominant gets implemented to the loads. Table 4.1 below shows the switching sequence of the loads.

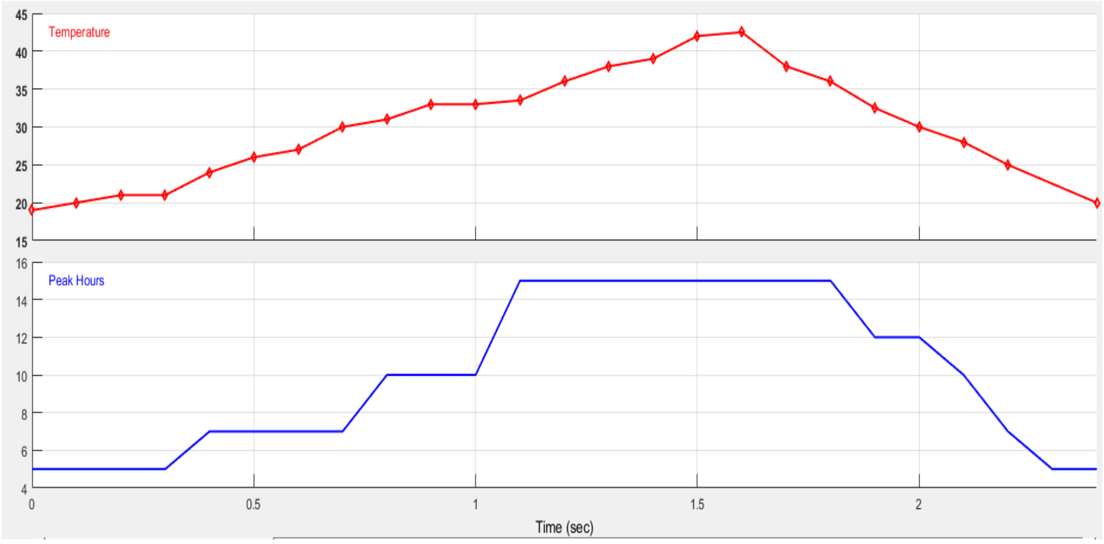

Figure 4.2: Temperature and Peak Hour curves

In figure 4.2, the curves of temperature and peak hours are exhibited. The values are varied from down to up from morning to noon and goes down afternoon to the starting temperature again. Similarly, the peak hours are increased in day timing and decreasing after 8 PM. For the real time implementation of optimization algorithm, the continuous variations of the curves are used as input of BRO in simulation.

Table 4.2: Load Switching for Lane 1

Sr.	Peak Hours	Temperature	Time of the day	Type -1 Load	Type – 2 Load	Type – 3 Load	Type – 4 Load	Type – 5 Load
1	LOW	LOW	DAY	Off	On	On	Off	On
2	MEDIUM	LOW	DAY	Off	On	On	Off	On
3	HIGH	LOW	DAY	Off	On	On	Off	On
4	LOW	MEDIUM	DAY	Off	On	Off	On	Off
5	MEDIUM	MEDIUM	DAY	Off	On	Off	On	On
6	HIGH	MEDIUM	DAY	Off	On	On	Off	On
7	LOW	HIGH	DAY	Off	On	Off	Off	Off
8	MEDIUM	HIGH	DAY	Off	On	On	On	Off
9	HIGH	HIGH	DAY	Off	On	On	On	Off
10	LOW	LOW	NIGHT	On	On	Off	On	Off
11	MEDIUM	LOW	NIGHT	On	On	On	Off	On
12	HIGH	LOW	NIGHT	On	On	On	Off	On
13	LOW	MEDIUM	NIGHT	On	On	Off	Off	On
14	MEDIUM	MEDIUM	NIGHT	On	On	Off	On	Off
15	HIGH	MEDIUM	NIGHT	On	On	On	On	On
16	LOW	HIGH	NIGHT	On	On	Off	On	Off
17	MEDIUM	HIGH	NIGHT	On	On	On	Off	Off
18	HIGH	HIGH	NIGHT	On	On	Off	On	Off

Loads are categories into five types of loads, as mentioned table 4.1. As the BRO is applied on the community, so two lanes are considered and each lane has five houses. All the same type of appliances of each house is grouped in Type-1 and similarly in the other types of category. The table 4.3 is shown the load switching mechanism of lane 2 of the same residential area. Temperature, peak hours and grid power will be same for both the lanes and used an input in simulation.

Table 4.3: Load Switching for Lane 2

Sr.	Peak Hours	Temperature	Time of the day	Type -1 Load	Type – 2 Load	Type – 3 Load	Type – 4 Load	Type – 5 Load
1	LOW	LOW	DAY	Off	On	On	On	On
2	MEDIUM	LOW	DAY	Off	On	On	On	On
3	HIGH	LOW	DAY	Off	On	Off	On	Off
4	LOW	MEDIUM	DAY	On	On	Off	Off	Off
5	MEDIUM	MEDIUM	DAY	On	On	Off	Off	Off
6	HIGH	MEDIUM	DAY	On	On	On	On	Off
7	LOW	HIGH	DAY	Off	On	On	On	Off
8	MEDIUM	HIGH	DAY	Off	On	On	Off	On
9	HIGH	HIGH	DAY	Off	On	Off	On	On
10	LOW	LOW	NIGHT	On	On	On	On	Off
11	MEDIUM	LOW	NIGHT	On	On	On	Off	Off
12	HIGH	LOW	NIGHT	On	On	On	Off	On
13	LOW	MEDIUM	NIGHT	Off	On	Off	On	On
14	MEDIUM	MEDIUM	NIGHT	Off	On	Off	On	On
15	HIGH	MEDIUM	NIGHT	Off	On	On	Off	Off
16	LOW	HIGH	NIGHT	On	On	Off	On	Off
17	MEDIUM	HIGH	NIGHT	On	On	Off	Off	On
18	HIGH	HIGH	NIGHT	On	On	Off	On	On

Chapter 5

Simulation & Results

CHAPTER 5 SIMULATION & RESULTS

5.1 System Design

The overall design of the proposed system is shown in the Figure 5.1. The setup consists of several blocks which will be explained later in this chapter. The system consists of a main utility grid with 220V, 50Hz AC signal. The source block transports the power to the attached loads. All the loads shown in the diagram below have different parameters. Each of these loads has its own category and power rating as explained in the previous chapter.

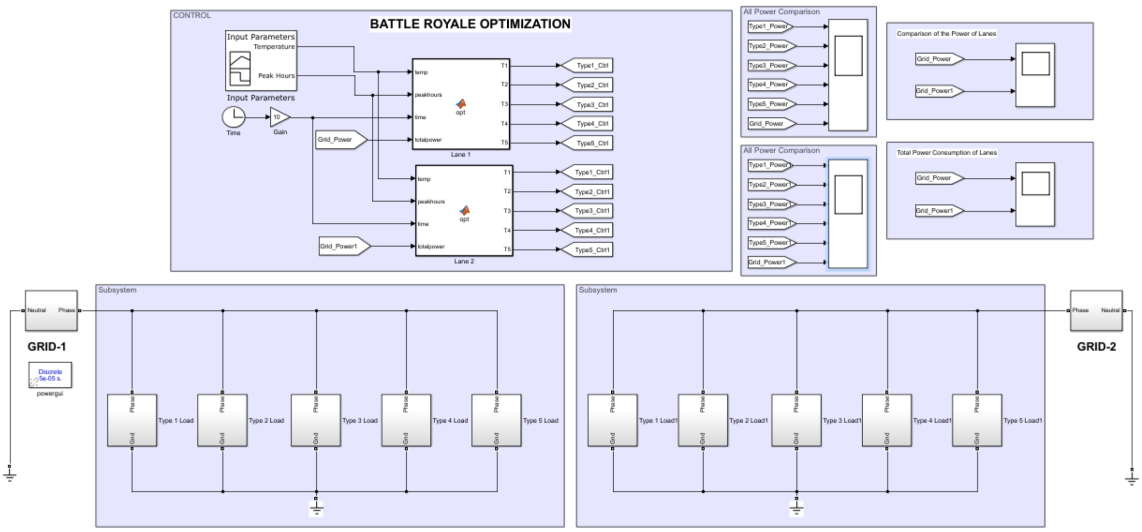

Figure 5.1: Overall Simulation Setup in MATLAB Simulink

It can be seen in the above figure that aside from the basic block, which is the grid and the loads, the simulation also consists of some other important components which are combined together in order to implement the proposed methodology.

The Battle Royale Optimization block explained in detailed in the next section contains an input parameter component which contains the data of peak hours and temperature for an entire day. It is worth mentioning here that the system performance can be checked on multiple configurations by changing the parameters. Aside from this, the system also checks the clock and power delivered by the grid in the simulations. All these parameters act as input to a function which takes the relevant values and generates the corresponding output signals for the load of switching.

The simulation also contains a scope segment which contains the power statistics of each of the connected load and the utility grid. The same statistics show the system performance and can be checked for multiple system configurations. Each of these blocks are described below to grasp the basic functionality of the all components that make up the entire system.

5.2 Power GUI Block

The power GUI block in MATLAB defines the simulation parameters. The most prominent parameter used in the power GUI block is the simulation type. The user can set the simulation type as continuous or discrete. The discrete type allows the user to set a sampling time. In the system, the simulation time of the power GUI block is set to default which is 50 microseconds. In order to get better results, the simulation time can be reduced even further however, doing this would make the simulation slower. The sampling time thus depends upon the nature of simulation and number of components in the simulation along with their detail and complexity. In other words, it can be said that there is always a trade-off between the sampling time and precision of results. Moreover, the solver type can also be adjusted as per the simulation requirement. The default solver used for this simulation is Tustin/Backward Euler. Figure 5.2 shows the internal parameters of power GUI block as mentioned above.

Aside from the main simulation parameters, this block also contains several analysis tools such as FFT analysis, load flow, impedance measurement etc.

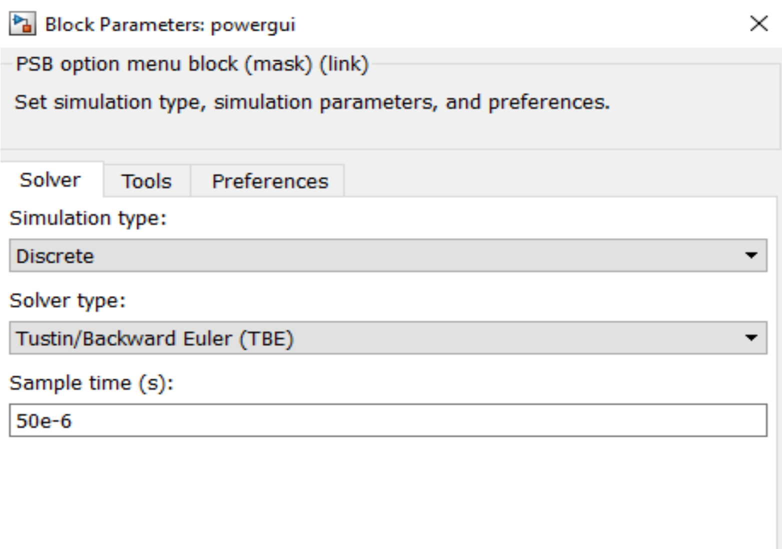

Figure 5.2: Power GUI Block Internal Parameters

5.3 Battle Royale Optimization Block

This block is parameterized using a MATLAB function block. The MATLAB function block allows the user to code rather than placing several components for algorithm implementation. This method reduces the simulation load and is time saving as well. The BRO block implemented in the system can be seen in figure 5.2 below.

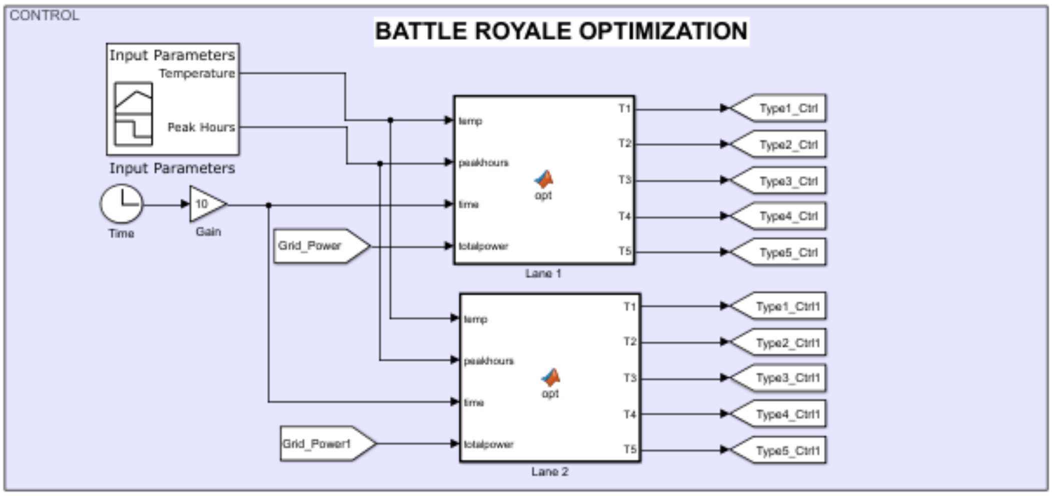

Figure 5.3: Battle Royale Optimization Block

In the figure above, aside from the MATLAB function block, some inputs and outputs are also a part of the algorithm. The components on the left represent the input parameters whereas those on the right represent output which is mainly switching signals to the load.

Two of the input parameters on the peak which are temperature and peak hours are already discussed in detail in the previous chapter. Aside from the two primary parameters, the input to the algorithm is the simulation time which is set to 2.4 seconds. This 2.4 second time is scaled to represent 24 hours of the day. A gain block translates the simulation time from 2.4 seconds to 24 which is then fed to the algorithm for onward processing.

The last input to the system is the feedback from the loads. This input translates the overall power consumption of the residence and feeds it to the algorithm. The design of the system allows it to monitor that the overall power consumption does not exceed a specified value which in this case is 6 KW.

The five outputs of the block represent the switching control of the five load types. Each of these loads contains a circuit breaker which allows it to connect or disconnect from the main power supply. The loads are scheduled as described in chapter 4 and the switching signals are sent accordingly to each of the load. In order to avoid cluttered connections, the “Goto” blocks are used. These blocks can take a signal from one place to another within the simulation without any actual line visible on the simulation canvas.

5.4 Load Block

The load block in the simulation serves its primitive purpose. The blocks are equipped with resistors, inductors and capacitors or their combination depending on the type of the load. Each of these loads contains a circuit breaker for the control along with the voltage and current measurement blocks. Each of the load block has two connections which is the ground and the phase. Figure 5.4 shows the internal structure of type 1 load.

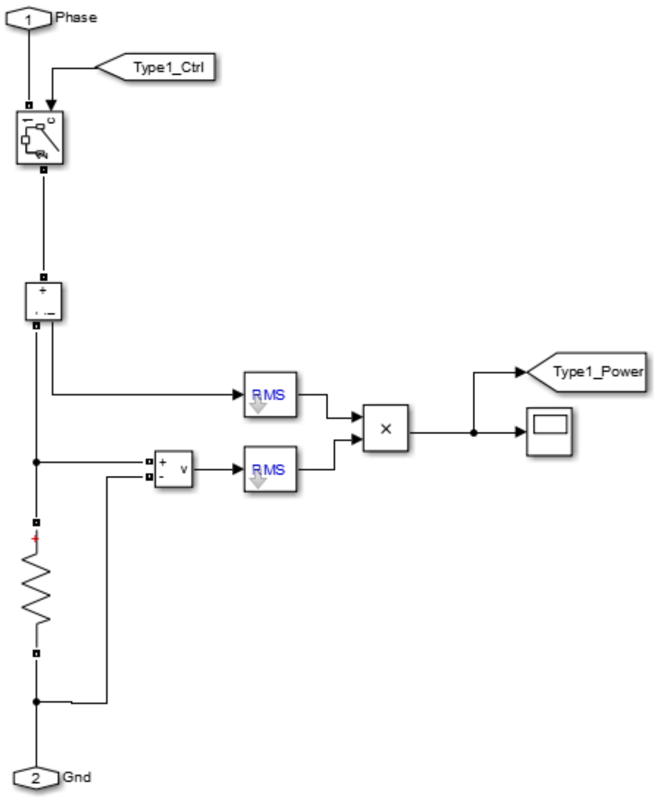

Figure 5.4: Internal Components of Type 1 Load

As evident from the figure above, the block contains a resistor as type 1 loads are normally resistive. Other types of loads in the simulation may contain one or more additional passive components as per standards. Moreover, a voltage and a current block is also attached with the load which is then passed through an RMS block to get the RMS value of both. The current and voltage are then multiplied using a product block to get the power consumption. The power of the load is measured and sent to the "Goto" block as described previously and can be extracted using a "from" block wherever required in the simulation. The circuit breaker on the peak of the load controls the power input to it. The input of the circuit breaker is from the BRO block.

5.5 Results

After parameterizing the variables and running the simulations, the results obtained are analyzed and checked. All the five load types as mentioned in previous chapter were embedded inside the same graph for proper analysis. Figure 5.5 below shows the results obtained from the simulations.

Each graph is presented in time and power domain. Horizontal plan is for Time domain and for better results each section is comprised of five hours. It means from zero to 0.5 time is equivalent to five hours, next one is representing the 10 hours and addition of five hours in each portion and so on. Whereas, the vertical axis is exhibited the power consumption by the power rating of appliances (load) and it is measured in Watts. In the same manner, all the graphs are plotted in time versus power consumption and last one the total power consumption by a single house or by the observed appliances.

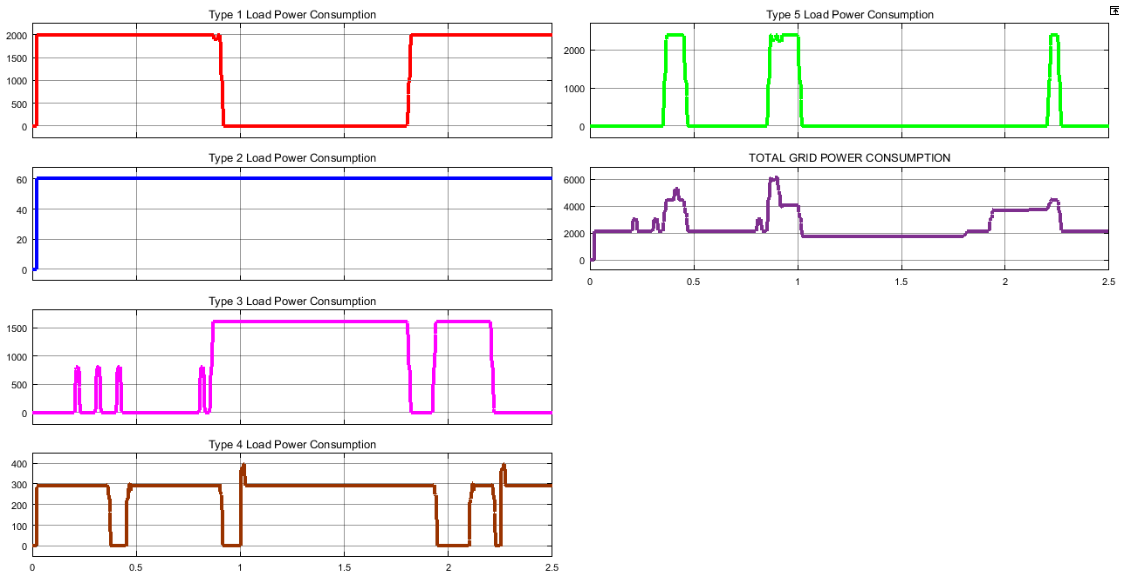

Figure 5.5: Simulation Results of Lane 1

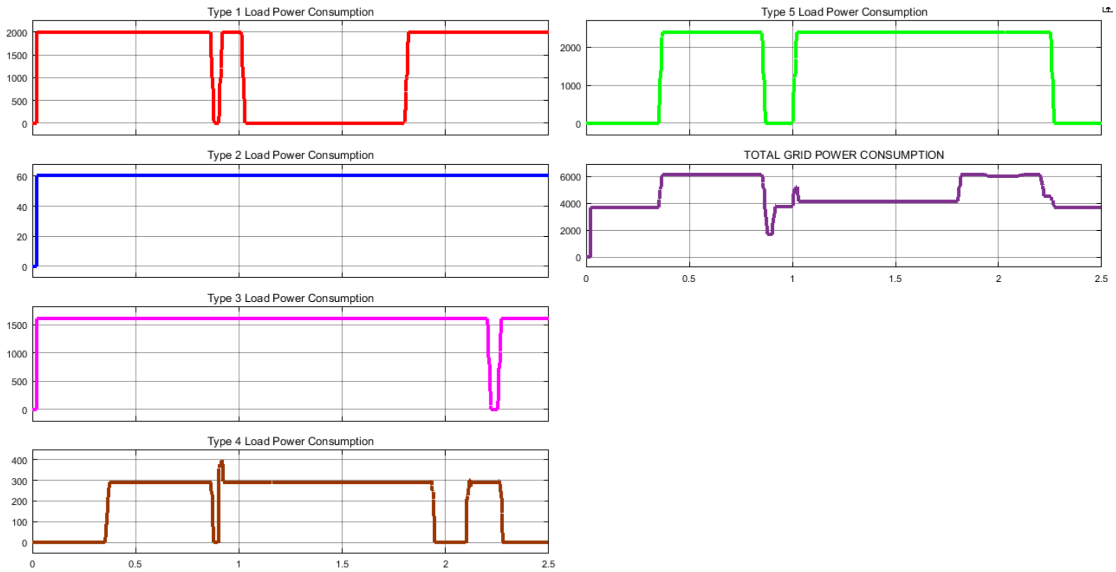

Figure 5.6:Simulation Results of Lane 2

As evident from the above figures, a total of six graphs are shown. The five graphs represent the load switching and their consequent power consumption whereas the sixth one shows the overall power consumption of the two lanes.

As shown in the figures, the first graph of type 1 load remains on continuously during a specific time and then turns off for some time. As described earlier, this load is scheduled type and can be scheduled by on and off-peak hours of the main power grid while maintaining the user comfort, cost reduction and minimization of PAR. Further, it depends upon the light intensity which in simulation is translated as day or night. Thus, the loads stay on during the night or dark and switch off during the day. This load can further be parameterized by using a light sensor in which case it would also be able to detect light intensity and switch specified number of lights when required.

The type 2 load graph shows that these loads stay on throughout during 24-hours. These are permanent loads and cannot be switched off as they are attached to the security and other surveillance systems. Generally, these loads comprise of sensors, actuators and motors which do not operate all the time, the load consumption of these loads as compared to any other load is very low. Permanent loads are selected by the low power rating so these can be turned off during operational state.

The type 3 loads which are the semi-permanent loads tend to switch as per the given conditions and parameters. The designed algorithm does not permit such loads to stay off for more than 02 hours. The same effect can be seen at the start of the graph where ripples can be seen. Due to the input parameters, the system shuts down the load but the other condition does not allow to stay off which in turn switches it back on. Thus, due to the flexibility of the system, these loads tend to turn on for half an hour to an hour even during peak hours thus saving energy without compromising user comfort.

Type 4 load graph reveals that the system permits such loads to keep switching as their power consumption does not affect the overall power drawn by the source. The maximum power consumed by these loads is 450 Watts approximately and system continuous to manage their switching accordingly.

The Type 5 loads are bulky appliances generally and are occasionally switched. For this reason, the system strategically manages their switching and also monitors their duration of operation. The system does not allow such loads to stay on continuously for more than 02 hours and thus shuts them down when the time limit is reached. As seen in the graph, the system manages the switching time and thus compels them to stay off during peak-hours.

The last graph in the above figure shows the overall power consumption. As mentioned earlier, the system also monitors the total power drawn by the residence of houses and does not allow it to exceed 6000 watts or 6 KW for lane and 10,000 Watts or 10 KW for lane two residents. For this reason, it can be seen that the overall power consumption tends to exceed beyond the allowed limit twice in the graph, but the system manages it by switching off the occasional loads and other unnecessary loads while maintaining the overall performance of the system. Therefore, the simulation shows that the system has an ability to overcome the load consumption for the reduction of per unit price of energy along with keeping in view the user comfort at desirous level. It is pertinent to mention here that, each type of load has same type of appliances of all the houses of the two lanes.

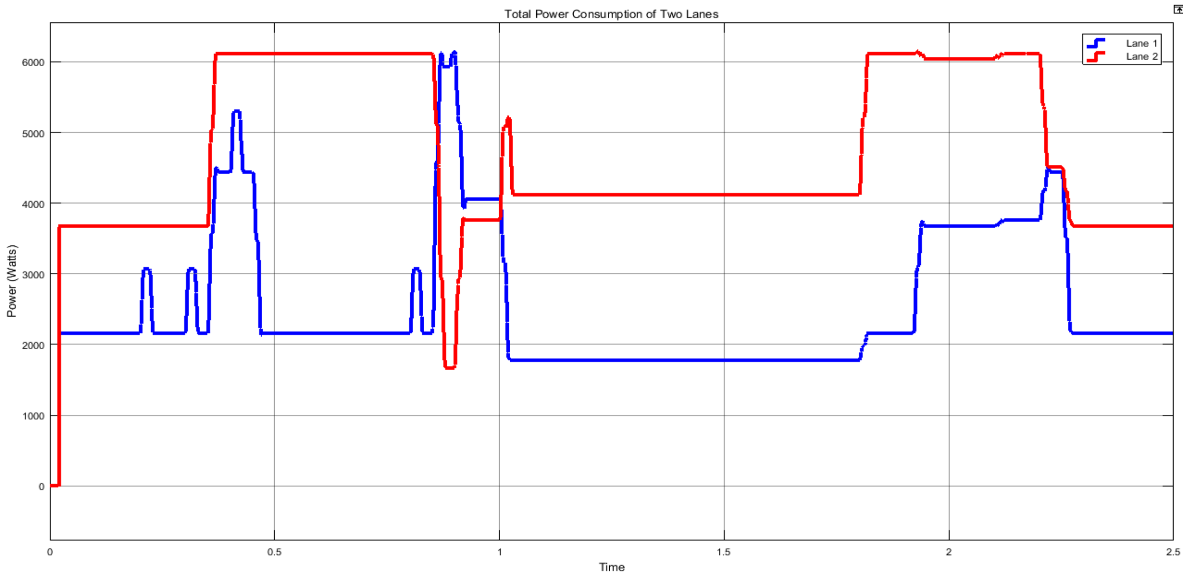

Figure 5.7: Comparison of Power Consumption of two Lanes

In the figure 5.7, the comparison of the total power consumption of the two lanes is shown. Blue color is representing the lane 1 and red color is representing the lane 2 respectively. As shown in the figure, the residential area of lane 1 having energy efficient devices at homes and is consuming less electrical power as compare to the lane 2. Moreover, the lane 2 residents have a greater number of appliances, so that the consumption of electrical power is greater than that of the lane 1 residents of the same area.

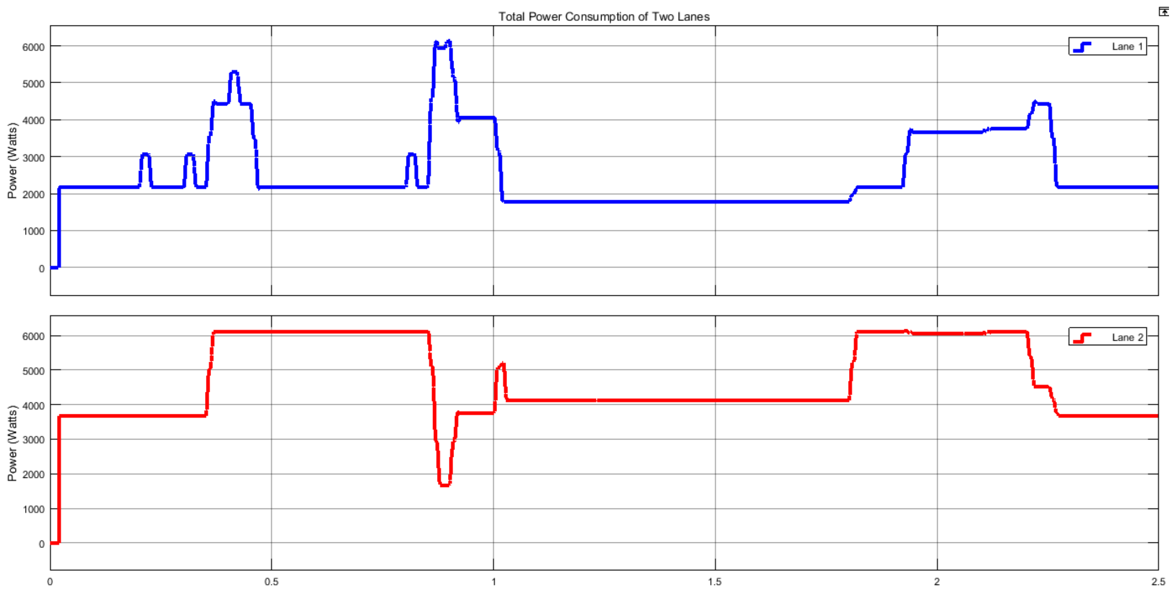

Figure 5.8:Total Power Consumption by Lanes

The figure 5.8 is representing the usage of electrical power of lane 2 residents starting from 3 AM to 9 AM than the lane 1 residents and these people are utilizing the double wattage as compared to another lane. But, at high peak hours, the unnecessary appliances are triggered off by the system for saving them from higher utility bills. Whereas, in the remaining hours, the consumption is much higher due to the installation of inefficient energy appliances at homes in lane 2.

Chapter 6

Conclusion and Future work

CHAPTER 6 CONCLUSION AND FUTURE WORK

6.1 Conclusion

The preliminary objectives of this research are to design and implement Battle Royale Optimization based algorithm for demand side management of electrical power on the community with minimizing the cost and maximizing the user comfort level. BRO is based on the Battle Royale games concept, the algorithm designed in this research treats the home appliances as soldiers and prioritize them over one another upon several parameters.

Therefore, for the development of intelligent electrical systems, the BRO algorithm is coded and applied on the DSM in MATLAB Simulink. First, the block of BRO has designed with the input of temperature, peak hours, time and power from the main grid. BRO block has five type of output as per categorization of loads.

Secondly, in order to reduce the complexity of the system, the output has shown in the scopes blocks and goto states are used in the same block diagram. Power grid has defined separately from the BRO block and linked in the same manner as output block has been connected with BRO block.

Thirdly, all types of loads of both lanes have been powered by the power grids and finally added to the BRO block. Besides the scope block, the comparison of total power consumption of lanes and results of each lane has been shown in output scopes.

From the results of scopes, as shown in graphical forms in chapter 5 of this research report that the appliances are controlled and monitored by using BRO algorithm and it reduced the power consumption by the residents. The results are also shown that, the comfort level of the user is not compromised while switching the timing of the appliances usage. The overall power consumption of the lanes is also being monitored by the system which does not allow to draw more power than the set power from the source which in lane 1 case is 6 KW and in lane 2 case is 10 KW.

6.2 Future work

It is worth mentioning that implementation of the proposed system is completely practical and economic. The system does not require any high processing hardware, only a personal computer with average specification would be able to monitor and control the entire system. Aside from that, as the system only utilizes the switching of appliances, the primary components for physical implementation of the proposed system would mainly require a processing unit such as a microcontroller and circuit breakers which makes the system inexpensive and practical.

The simulation setup assumes that the environment can be varied and the system is operational in normal sunny day. The weather conditions are unpredictable and the climate may also vary for different locations. By extending the ranges and create multiple threshold values, the robustness and reliability of the system can be enhanced. It can be used in real time application of engineering numerical. A single soldier is selected as best elite, but for the future researcher the team of soldier or force can be selected as best elite team and space of battle can be enhanced than for the single player mode.

In the research work the two lanes are considered as community for deployment of BRO algorithm. The same research can be extended to corporate sector such as offices, industries with bulky machines and other such communities which are not taken into account in this study. The proposed system can also be enhanced further by considering these parameters with other required parameters of the corporate sector. This means that a factory might not have a type of machine which can be turned off after specified period. Thus, by defining more types of appliances, the system can be enabled to entertain other sectors and be implemented right away without much extra cost or setups. The system can also be extended further to be able to control a number of residences and sectors altogether without the need of individual installation for every house, office or factory.

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