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Effects of Demand-Side-Management on Frequency Actuated Load Shedding

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ABSTRACT

Presented paper is focuses on Demand-Side-Management and how it affects frequency and Load-Shedding (LS). The Demand-Side-Management makes the customers aware about the amount of energy, theyconsume. To balance demand and generation side, we have Under-Frequency Load shedding(UFLS), as frequency plays a vital role in maintaining the balance between demand and generation side.

We have used MATLAB/SIMULINK simulation, providing the knowledge about when and where to shed a load in contingency condition.

IndexTerms— Load shedding, black out, smart meter, Demand-Side-Management, under-frequency.

1. INTRODUCTION

Electricity is something, most of us take for granted but still many masses are without access of electricity and its demand, nowadays, is increasing and will increase over the coming years. Under-frequency in an interconnected power system is not acceptable as it likely results into cascaded tripping of generating sets, leading to blackout. As electricity is essential commodity in day to day activity and as its demand is continuously increasing, it results into Supply-Demand gap. This gap or the difference results into drop of power frequency, termed as 'under-frequency'. Finally, this under-frequency will lead to blackout. There is no denying the fact that how important is the electricity in our day to day life, but the sources of electricity are ample in number than that of demand asked by consumer. So, we have tried to find out the general solution for it. And that is Demand side management. Demand side management being set of interconnected programs,lets the customersto shift their demand for electricity during critical periods and thus, reduces the consumption of energy, overall. So, itbecomes an effective tool that improvesenergy efficiency and promotes conservation of energy.

Demand side management or DSM is the process through which a power utility manages the demand for power/energy among some or all its customers to meet its current or future needs. It comprises all planning, implementing and monitoring activities and measures designed to improve efficient use of energy and encourage consumers to modify their level and pattern of usage. With the help of demand side management, the frequency can be controlled and accordingly load shedding is applied to grid, this is called as Under Frequency Load Shedding (UFLS).

There are four basic principles of supply and demand of electricity and those are:

- If supply remains constant and demand goes on increasing, thenshortage occurs and higher equilibrium price will occur.
- If supply remains constant and demand lowers, a surplus occurs and lower equilibrium price will be there.
- If there is increase in supply and demand remains constant, a surplus occurs and leads to a lower equilibrium price.
- If there is decrease in supply and demand remains constant, a shortage occurs and results in higher equilibrium price.

Power frequency reflects the load generation balance in the grid at a particular instant. Frequency is one of the most important parameters for the quality of power supply in any grid and assessment of the security of power system. It is to be maintained within the optimum range so that all the electrical equipment should perform safely and efficiently. The integral part of market design, nowadays, is handling imbalances. The balancing market is basically frequency dependent, in case of India and market design must possess reliability. This paper focuses on grid frequency, rather than ice landed area and other issues related to grid security. It also gives the better ideas about how to control demand at demand side by simple use of Smart Meter, as for customers, the load shedding concept is disadvantageous because they can’t make access of electricity. The MATLAB/Simulink model is helpful to get knowledge about how and when to apply load shedding.

2.LITERATURE REVIEW

The imbalance between active power generation and consumption directly reflected in a system frequency deviation [1]. Dynamics of under frequency during the deficiency of generation in the power system can have very different characters. It depends on the value of disturbance, response of emergency automation, governor system and reasons of emergency situation [2]. The reasons for the occurrence of high-level active power imbalances may be a sudden change in the system load, the sudden outage of a large generating unit or the sudden outage of transmission lines. Restoring frequency load shedding or spinning requires the reserve involvement [3,4]. An interconnected electric power system or grid-type electric power system must balance load and generation, in order to maintain frequency range, within optimal range. If the system's frequency falls below a specific value i.e. 50Hz, under frequency protection becomes major part of available system. Firstly, under frequency load shedding (UFLS) was introduced in New Zealand in 1965 with the help of HVDC link.

In India, firstly under frequency load shedding schemes were implemented in Northern Region (NR) of India in 1987 to take care of sudden outage of the largest generating station i.e. 2000MW Singrauli STPS (Super Thermal Power Station) in Sonebhadra, Uttar Pradesh. While implementing this system, specifically under frequency was taken into consideration, in converse to over frequency.

2.1 Demand-Side-Management

In order to increase the efficiency and hold the line of cost, "Customer" has become as a new utility corporate planning option along with a utility at each hour. Since the early1970s, technological, economic, social, and resource supply factors are combined to change the operating environment of energy industries and its outlook for the future. Many faced scattering capital requirements for developments of new plants, declining financial performance, significant fluctuations in demand and energy growth rates, and political or regulatory and consumer concern about rising prices. While demand-side-management (DSM) is not a cure for all for these difficulties, it provides many additional alternatives. These alternatives are equally appropriate by utilities, energy-service suppliers, suppliers and government entities [5].

There are 3 types of Demand-Side-Management (DSM).

1. Energy Efficiency: Using the less power to perform the same tasks

2. Demand Response: Itincludes any preventative method for flattening, reducing or shifting peak demand. Demand Response includes modifications for consumption patterns of electricity of end user customers. That is intended to alter the timing, the total electricity consumption level of instantaneous demand. Demand Response uses wide range of actions, taken at customer side of the electricity meter, which giveresponse for particular conditions within the electricity system.

3. Dynamic Demand: To increase the diversity factor of set of loads, the advance or delay appliance operating cycles are added. Theconcept usedis that by examining the power factor ($\cos\phi$) of power grid, also their individual control parameters, individual intermittent loads would beswitched on or off at the optimal points. This is done to balance the overall system load, with generation, reducing the critical power mismatches. As it's switching will only advance or delay the appliance operating cycle by few seconds, it would not be noticeable to the end user. In 1982, in US, patent for this idea was issued to power systems engineer Fred Schweppes. Figure 2.1 shows the major impact areas of DSM

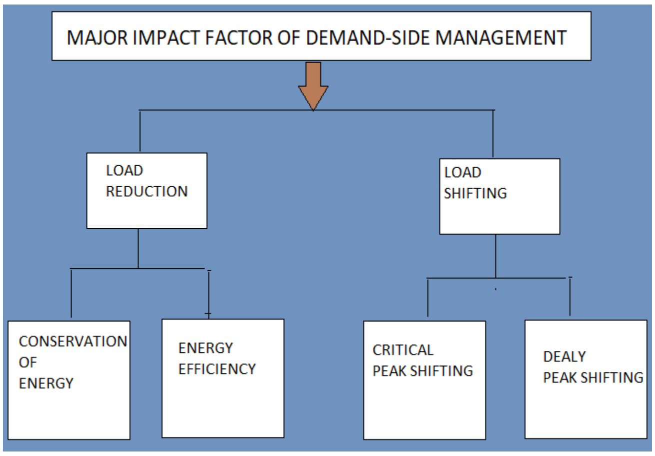


Figure 2.1: The major impact areas of DSM

For growth of strong load, load management, and strategic conservation can reduce or postpone construction of new generating facilities. For others, electrification and deliberate increases in the market share of energy intensive uses can improve the utility load characteristics and optimize asset utilization. Besides these cases, changing the load shape that an energy system can reduce operating costs changes in the load shape can permit adjustments in plant loadings, thus increasing the use of more efficient plants and permitting the use of more domestically abundant and less expensive energy sources. In the residential sector, cost control/consumeroptionsgivethecustomersomecapabilitytocontrolmonthlybills [5,6].

2.2 Under-frequency load shedding (UFLS)

An interconnected electric power system (Grid system) must balance load and the generation, in order to maintain the frequency within the optimal range. Under-frequency protection schemes should be employed, if system frequency falls the given threshold value. Under-frequency load shedding schemes is design for the use in extreme conditions to stabilize the balance between load and generation [7]. All synchronous generators in Northern Region are designed to operate at 50 Hz i.e. 50 cycles per second. And specifically, frequency will be the major content to decide whether how well our load and generation are balanced. If there is more load than generation, at any moment, frequency will drop below 50 Hz and conversely, frequency will rise the specified level when generation is more than that of load. Therefore, the basic idea of Under-frequency load shedding schemes is a safety net that will help us to prevent the complete blackouts of the grid-type electric power systems. UFLS is not effective if there is electrical instability or voltage collapse within the grid-type electric power system.

Also, UFLS programs are designed for the specific area or system and they are commonly implemented with devices installed on the distribution side of power system.

2.3 Mathematical Model

Minimization of load shedding during contingency conditions is solved as an optimization problem. Instead of local load shedding, total load shedding of a large power system is considered [8,9]. Power generation rescheduling is considered to minimize the load shedding. The linear programming method (LP) is used to solve this problem in a short period of time without considering some power system constraints [9]. Particle swarm optimization (PSO) is used to solve problem by considering all power system parameters, but it isdone with a longer solving time. Finally, a new method, the sequential use of LP and PSO, is proposed.It isthe fastermethod than PSO [10].

2.4 MATLAB/Simulink

Simulink is developed by Math Works. It is a data flow graphical-programming language tool, used for modeling, simulating as well as analyzing the multi-domain dynamic systems. The primary interface of MATLAB/Simulink is a graphical block diagramming tool and a set of block libraries. It integrates the rest of the MATLAB environment and can either drive MATLAB or be scripted from it. Simulink is widely used in control theory and digital signal processing, which is again used for multi-domain simulation and Model-Based Design [10].

3. SOLUTION METHOD

3.1 Linear programming algorithm

Linear programming, and its application in electric power systems, is popular andis used as an optimization technique in many papers. In contingency analysis, the most interesting limits of the power system are branch flows and bus voltages. Considerably more attention has been paid to branch flows than bus voltages. This has resulted in risein extensive use of linearized active power models. The DC power flow model is too dubious in accuracy for use on most power systems. The use of an active power model makes an assumption that voltages and reactive flows change very little after a contingency. This assumption is most valid for strong high voltage transmission systems in which branch R/X ratios are small [11].

3.2 PSO algorithm

This algorithm is defined as follows:

1. Formation of initial population and initial velocities randomly.
2. Calculation of the value of each particle by fitness function.
3. Finding of the local best of each particle.
4. Finding of the global best of all the population.
5. The PSO algorithm updates the velocity for each particle, then adds that velocity to the particle position or values. Velocity updates are affected by both the best global solution with the lowest cost ever found by a particle and the best local solution with the lowest cost in the present population.

3.3 Sequential LP and PSO algorithm

As mentioned, the LP algorithm is appropriate for fast calculations, but in this method, the network cannot be modeled accurately and the network constraints are not considered completely [6]. With the helpof PSO algorithm, it is possible to consider the nonlinear model of network and its constraints accurately. Unfortunately, the PSO algorithm needs more time for calculation in comparison with linear programming. In order to achieve a fast solution in addition to considering all necessary constraints, the LP and PSO algorithms were used sequentially as a new algorithm in this paper [7]. In the proposed method, the solution obtained by the LP method was used as the initial population in the PSO algorithm. The PSO started its search from the vicinity of the optimum solution. In this way, it was possible to solve the nonlinear model of the system in a shorter time than that of PSO.The Figure 3.2 gives the short description about the process of sequential use of LP and PSO.

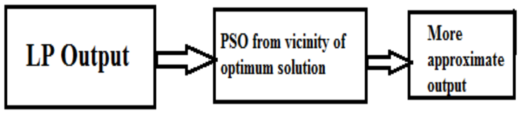


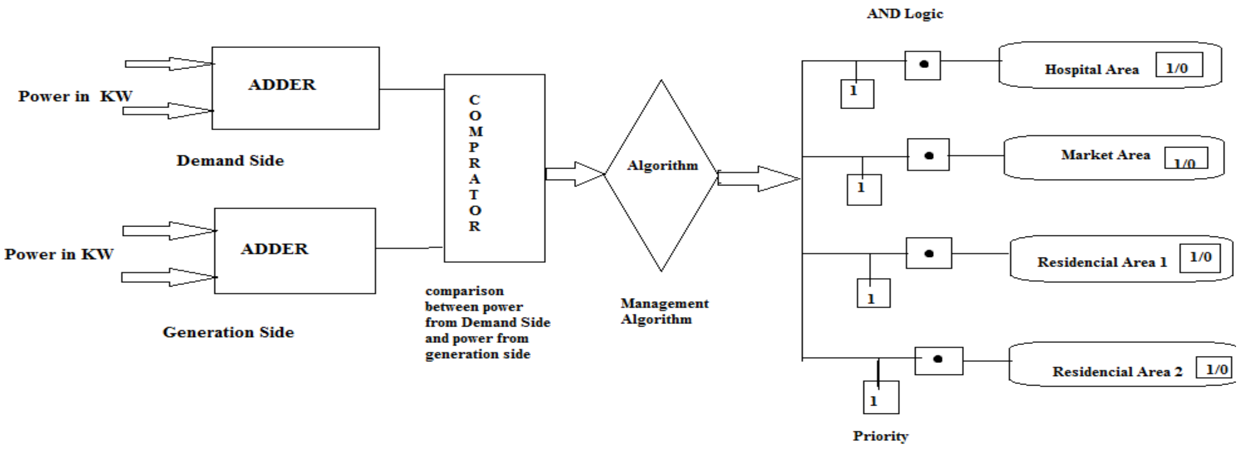
Figure 3.1: Proposed algorithm

3.4 MATLAB/SIMULINK MODEL

MATLAB/Simulink version: Simulink 8.1 R2013b

In MATLAB/Simulink you can draw the blocks of user defined functions and can see the simulation results. The block diagram, as shown in Figure 5.1 is the simulation model we have studied and simulated results. MATLAB/Simulink is used to get the desired output [14].

Figure 3.2: Block Diagram for simulation in MATLAB/ Simulink



In the left side of diagram, as you can see, there are two sides: first one is demand side and other is generation side. In real time system, the generation and demand should match each other to have a perfect power system. But there are always fluctuations in generation and demand side. And this is the reason why frequency too varies. Varies, here, means frequency goes low to the rated value and black out occurs. This under frequency produces its effects on the residential areas, hospital area and market area we have connected to the power station. Demand side is completely based on the consumers.

The power on the demand side is in kilowatts. As well as, the power at generation side is also in kilowatts. All the power from the demand side get added with the help of adder as shown in Figure 3.1, as well as the addition of power is taken place at the generation side too. These powers from demand side and the generation side are then compared with the help of comparator, as shown in Figure 5.1 above. As we have discussed earlier, whenever demand will be greater than that of generation, frequency will go low. So, our main goal is to balance demand and the generation, so to avoid the under frequency, thereafter the effects of under frequency i.e. load shedding application. This is not necessary that demand should go low every time. This may also happen that, generation too can go low and demand remains constant, that time also frequency goes low and load shedding is applied.

Adder: Adder or summer is a digital circuit that performs addition of numbers. Here, the addition of power from demand and the generation side is done.

Comparator: The comparator is the device which compares two voltages or currents and outputs a digital signal indicating which is larger. Here the comparison of power takes place. As power is the product of voltage and current. It can be seen by the formula (18) as:

$$\textbf{Power } P = V \times I = \text{R} \times I^2 = V^2 / R \quad (18)$$

A comparator consists of a specialized high-gain differential amplifier. Comparators are commonly used in devices measuring and digitizing analog signals, such as analog-to-digital converters (ADCs), also relaxation oscillators.

To save the power grid from these sudden changes in frequency, we can have many solutions. One solution is to use the smart meter at the customer end. The details of the smart meter are as follows.

3.5 Smart Meter

Confusion over smart meters is rife. We’ve found that many people don’t know the difference between a smart meter and an energy monitor, and several people who think they have a smart meter actually have an energy monitor.

Figure 3.3:Smart meter

3.5.1Working

A smart meter communicates directly with your energy supplier.Therefore, there is always an accurate meter reading and there is no need to take a meter reading yourself.Smart meter works in different ways, which includes using wireless mobile phone type technology to send data. Fig 3.3 shows the working of smart meter.

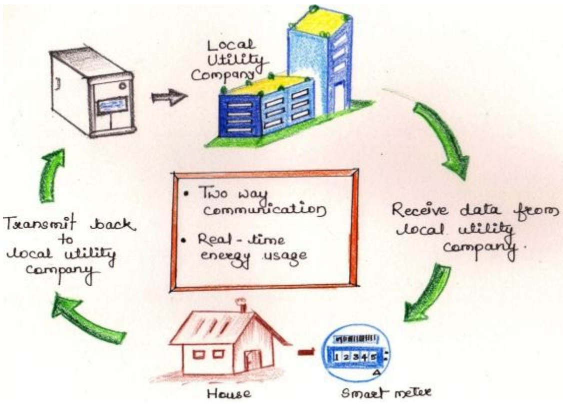


Figure 3.4: working of smart meter.

Here the restricted area is the hospital area. And the other areas are set in terms of priority. When the priority is set i.e. (1), all the areas will be taken into consideration and accordingly the load shedding is applied.

4. EXPERIMENTAL RESULT AND DISCUSSION:

This has been proved with the simulation. And its results can be shown below in Figure 5.4, Figure 5.5 and Figure 5.6 respectively. In Figure 5.4, adder at demand side collects 500kW power, while the Generation side adder collects 1000kW. At this time both Demand is lesser than that of generation. And if the availability is more than that of use, there is no doubt in shedding the load. So, there will be no change in the frequency and it will be equals to 50Hz. And this time, all the loads will be ON (1). Here hospital area is always at position 1 i.e. it will be always in ON condition at any cost. The other areas in our model are residential areas which will be at position (1) i.e. ON state and also the market area too will at ON.

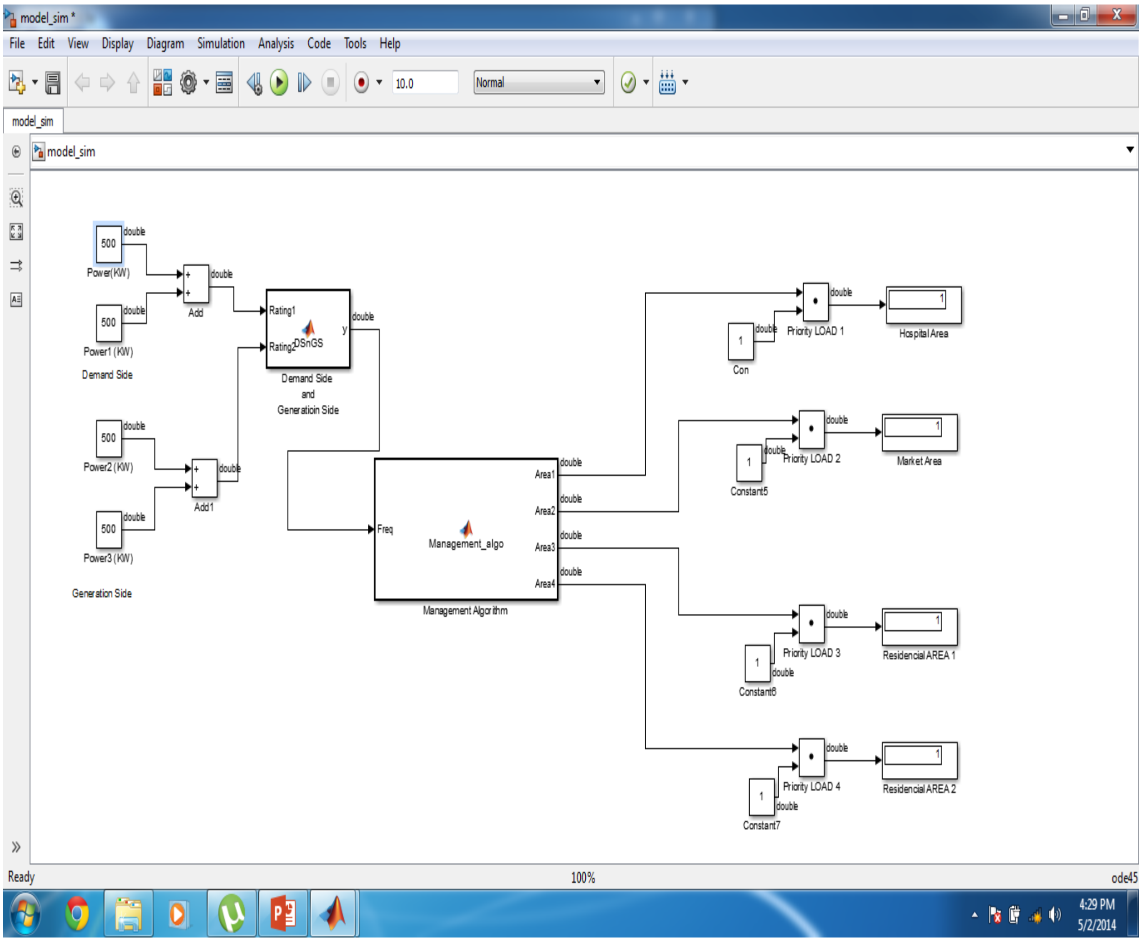
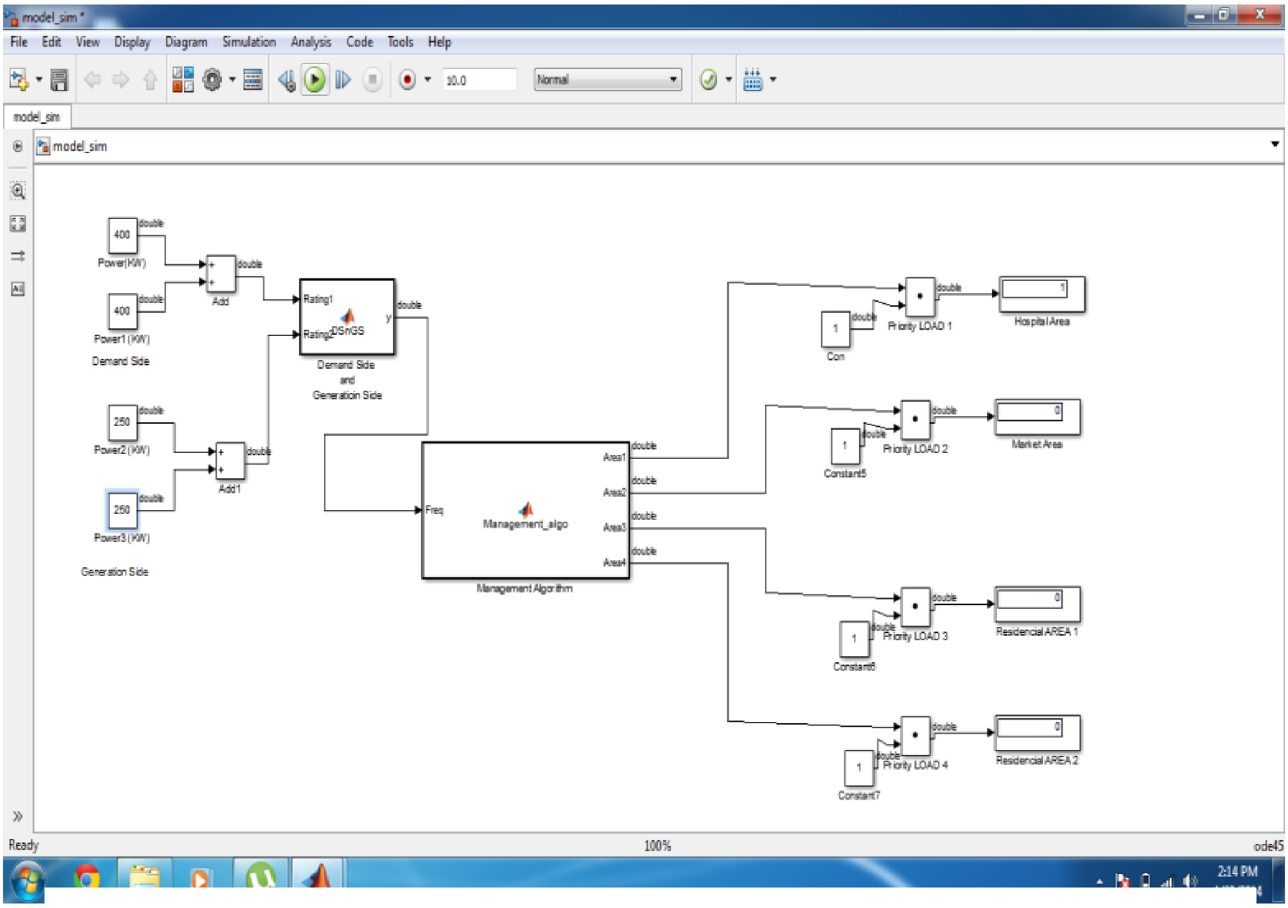


Figure 4.1: When generation is greater than demand

In Figure 4.1, adder at demand side collects 1000kW power, while the Generation side adder collects 1000kW. At this time, both Demand and generation have the equal power and there is no gap in between demand and eneration. So, there will be no change in the frequency and it will be equals to 50Hz. And this time, all the loads will be ON (1).

Figure 4.2 When Demand is exactly same as that of Generation



In Figure 4.2, adder at demand side collects 800kW power, while the Generation side adder collects 500kW. At this time, Demand is greater than that of generation side. So it affected the frequency and frequency is fallen down to 49.5Hz, as a result the loads except restricted areas are shed.

Here, the restricted area is the hospital area, which is unaffected, although there is gap between demand and generation, as the priority is set to it. And the other areas such as market area and two residential areas are affected by the falling frequency and the loads are get shed. This can be seen from Figure 5.6 in detail. The all areas are at position (0) i.e. load shaded, except hospital area

5.CONCLUSION AND FUTURE SCOPE :

5.1 Conclusions

In order to reduce the probability of emergency situations under normal and pre-emergency conditions it necessary to observe security requirements; especial attention should be paid to the situations that can give rise to additional disconnections, which, in turn, can cause blackout development. As the practical results can't be carried out by visiting the power station, the practical knowledge of effects of demand side management on frequency actuated load shedding schemes is usually carried out with the help different mathematical methods such as, Linear programming, practical swarm optimization as well as simulation programs of the real power network, here typically MATLAB/Simulink will be used.

And finally the study of results of both mathematical model and simulation in MATLAB/Simulink will be done.

5.2 Future Scope

- Various algorithms based on critical line overloads can be implemented to reduce network cascading failure.
- Restoration model can be achieved when frequency comes to its normal value i.e. 50Hz.

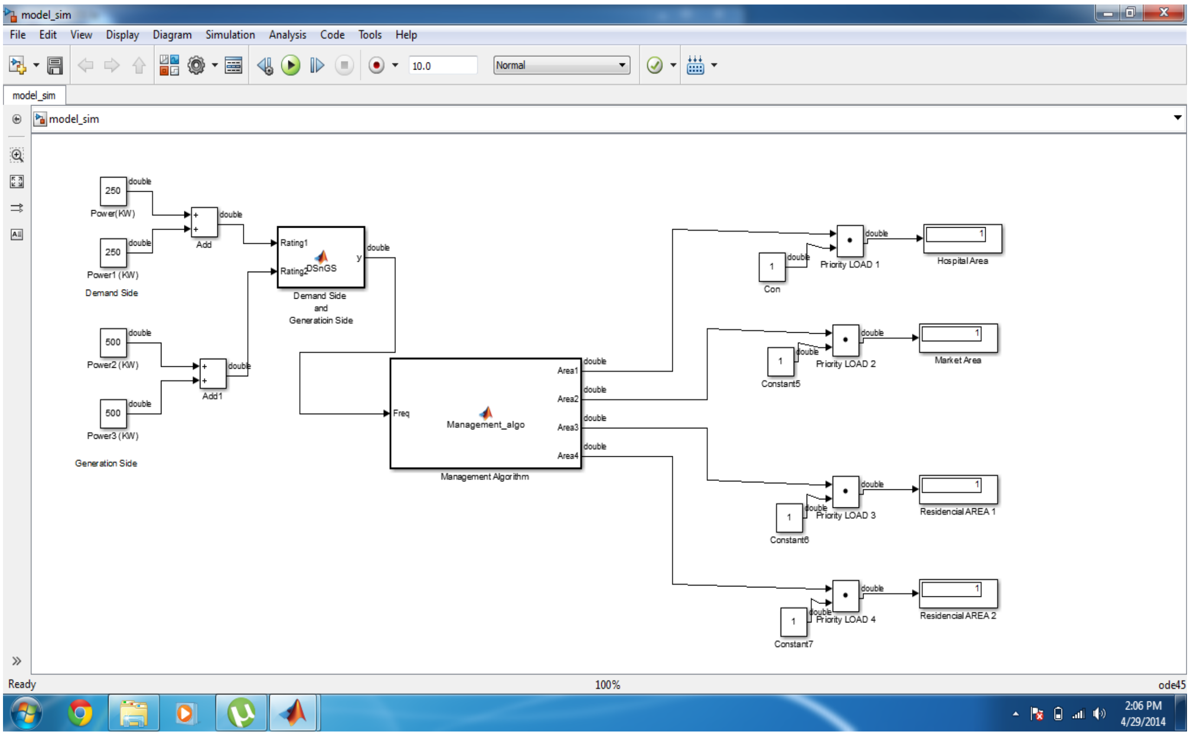


Figure 5.7: When, demand is greater than generation

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