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ANN Based Frequency control of Thermal Loads and Power Transfer in Smart Grids

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ABSTRACT

Smart Grid is an Electrical Grid with Automation, Communication and IT systems that can monitor power flows from points of generation to points of consumption (even down to appliances level) and control the power flow or curtail the load to match generation in real time or near real time. The power system frequency may be subjected to a severe drop without a balanced power between generation and load demand side. The load-frequency control (LFC) is used to restore the balance between load and generation in each control area by means of speed control. The objective of LFC is to minimize the transient deviations and steady state error to zero in advance. This paper investigates LFC with time delays using a simple algorithm for primary control and tie line power transmission for secondary control using MATLAB/SIMLINK. In this proposed system Area 1, 2 and 3 are connected by normal AC tie-line. An analytical study is made. The advantage of incorporating time delays is important for satisfactory dynamical responses. The transmission link is to transfer power over long distance without any frequency deviation. An algorithm is designed with ANN(Artificial Neural Network) based controller incorporated in each of the zones to study how it outstands the existing controller techniques.

KEYWORDS: *Smart Grid, Load Frequency control, Steady State error, power transmission, ANN*

INTRODUCTION

A power generating system has the responsibility to ensure that adequate power is delivered to the load, both reliably and economically. The quality of power supply is affected due to continuous and random changes in load during the operation of the power system. Hence, a power system control is required to maintain a continuous balance between power generation and load demand. Load Frequency Controller and Automatic Voltage Regulator play an important role in maintaining constant frequency and voltage in order to ensure the reliability of electric power. In order to improve the performance and stability of these control loops, proportional-integral-derivative (PID) controllers are normally used. But these fixed gain controllers fail to perform under varying load conditions and hence provide poor dynamic characteristics with a large settling time, overshoot and oscillations. In order to achieve a better dynamic performance, system stability and sustainable utilization of generating systems, PID gains must be well tuned. Power system stability is a critical topic in the new smartening trend. The power system is an operation which can be modelled dynamically with wide-scale multi-inputs/outputs and other variables. The instability of a power system can result from unplanned con- tingencies, such as short circuits, sudden overloading (OL) and gen- eration unit outage. These events may cause power supply imbalance between generations and loads. This deviation results in frequency drops that may cause critical power system instability problems. Consequently, disastrous phenomena, such as overloaded transmission lines or reduced quality of supply service, may occur.

Recently, the concept of wide-area frequency control becomes a considerably important research area. Power network is confronted with many challenges concerning power system stability, network self- healing and power supply life period. Hence, the frequency control of wide area system is a critical issue. An emergency control system considers large contingencies that cause large frequency excursions. Although these conditions occur rarely, they are the reason of blackouts during the last decades due to cascading failures of operating traditional control schemes. Under frequency protective relays are the traditional schemes used to prevent the tripping of generating units by reducing the connected loads to a level that can be safely supplied by an available generation. This technique may cause blackouts at different levels due to the response delays of the loads located at area farther than disturbed areas. Moreover, the probability of cascading operation failure increases.

The process of smartening power grids must provide an alternative solution to improve grid robustness, reliability and security at frequency control. This upgrade can be supported by a series of advanced communication infrastructures and new measurement innovations. The communication infrastructure is critical for the application of both centralized and decentralized control schemes. Many researches consider the communication time delay at decentralized control scheme. On the other hands, the centralized control scheme confronts the problem of complexity.[1]

LOAD FREQUENCY CONTROL FOR SMART GRIDS

A. Frequency control loops:

Frequency stability and control is one of the most important problems in interconnected power grids design and operation. Several control loops are operating to maintain the system frequency at its set-point. Each one has its particular specification and relies on a given amount of power reserve that is kept available to cope with power deviations. The majority of supply-demand balancing is achieved by controlling the output of dispatchable generating units.

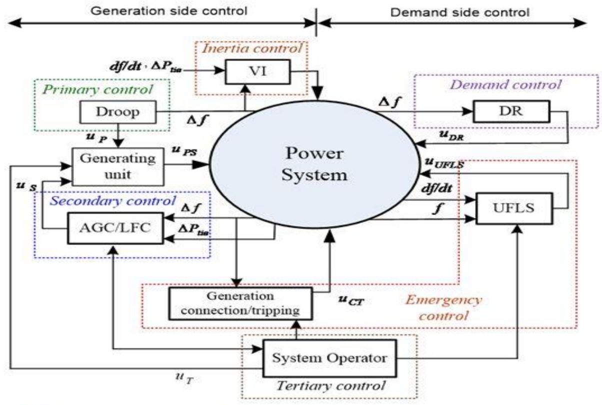

Fig. 3. Frequency control loops in modern power systems.

Figure1-Frequency control loops in modern power systems

B. Problem statement and objectives:

In this paper, we are simulation three area system in which each single area consists of three phase grid, multiple loads including controllable Air Conditioning (AC) loads. The primary control provides the temperature set point to the AC loads depending on the load frequency. The secondary control provides the required additional power from other areas by the tie lines.

The objectives are to control the power demand by controlling temperature setting of the coolingsystem i.e to change the temperature of HVAC loads and reduce power consumption, Determining excessive demand using deviation in systemfrequency and mainly to prevent blackouts and loss of synchronization upon varying load requirements and maintain balance in frequency and voltage using temperature controlcircuit.

C. Block Diagram – Proposed model for Smart grids:

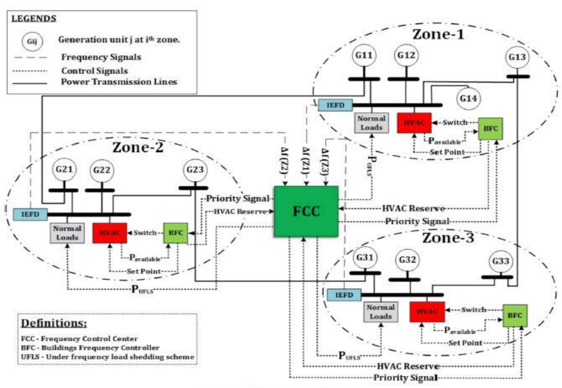

Fig. 2. Frequency control system model.

Figure2-Frequency control system model

D. ANN - Principle:

Here, each zone consist of R loads and Air Conditioning Loads. The AC Loads is controlled by ANN. The load frequency is measured and compared with the refernce frequency. Error frequency is given to ANN controller. ANN controller provides the Temperature. From temperature, power is calculated, this consumption is given to the loads. As per temperature, the power limits changes accordingly. This inturn result in controlling of frequency.[15]

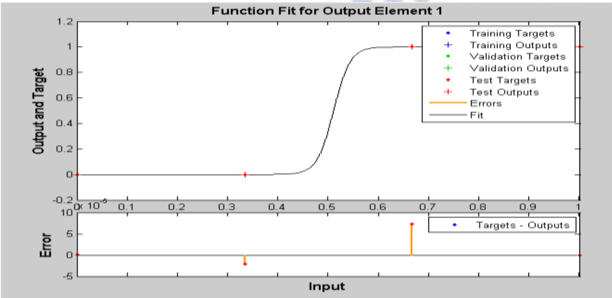

Figure3-Fitting curves from neural network training

II. METHODOLOGY

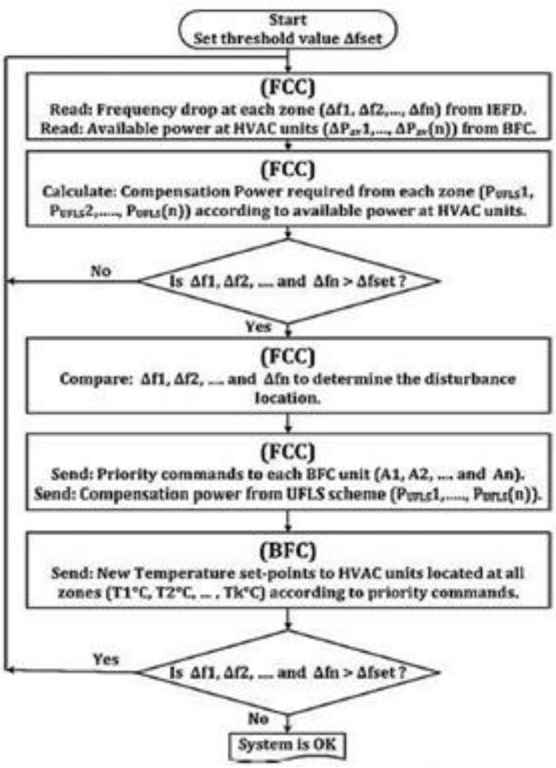

FIGURE4-CENTRALIZED HIERARCHY FREQUENCY CONTROL ALGORITHM BY USING HVAC UNITS

Process: The algorithm works as per following flowchart based on comparison of temperature, controlling power and thereby controlling frequency. Overloading sequence used in circuit: Zone one intially has 1 R load, 2nd R load after 1sec, 3rd R load after 2sec. Likely Zone2 - 1st R load after 3 seconds and Zone3 - 1st R load after 4 seconds.

III. COMPARISON OF OUTPUTS

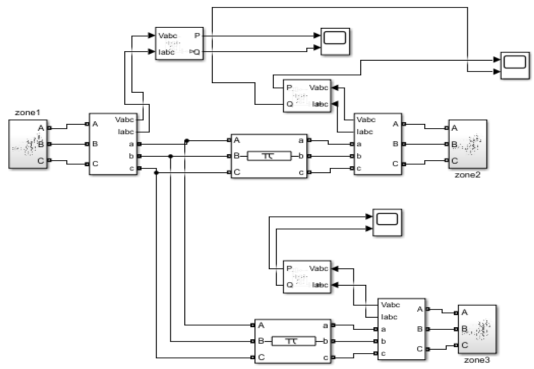

Figure5-The simulation circuit of the three area system with interlinked tie lines

In this, three different ares are interconnected with each other by transmission lines.

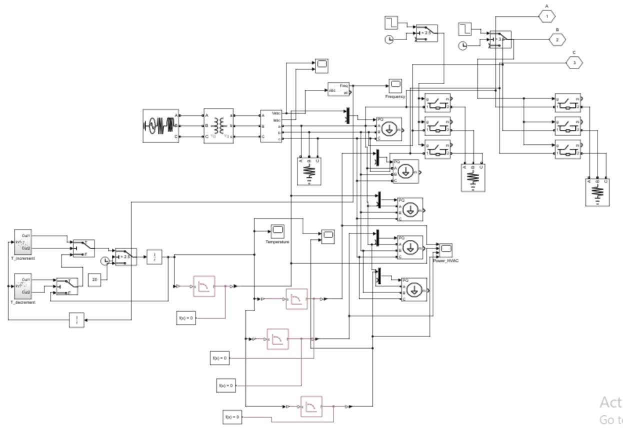

Figure6-The simulation circuit for area1

In this, three loads are connected along with five HVAC loads. Initially load1 is connected from t=0. When t=2.5s, load2 will be connected and when t=3.5s, load3 will be connected. Due to this excess loads, the power demand increases where as the supply is constant. Hence the frequency starts to deviate. To avoid that, the temperature of the HVAC loads are varied accordingly so that the power consumed by the HVAC loads are controlled in order to get the frequency recovered.

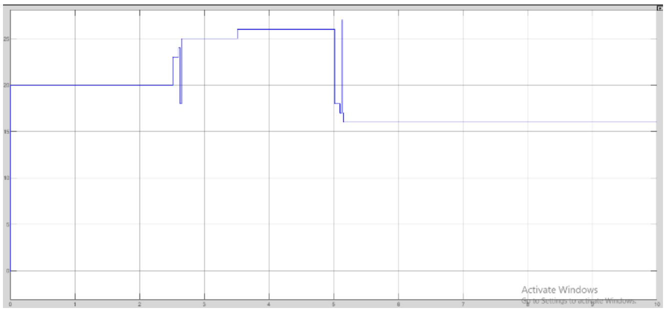

Figure7-The temperature setpoint from the controller

In this, the frequency is reduced and hence the temperature is increased in order to reduce the power consumption of the HVAC loads. When the excess loads are disconnected, the temperature reduces at t= 5s.

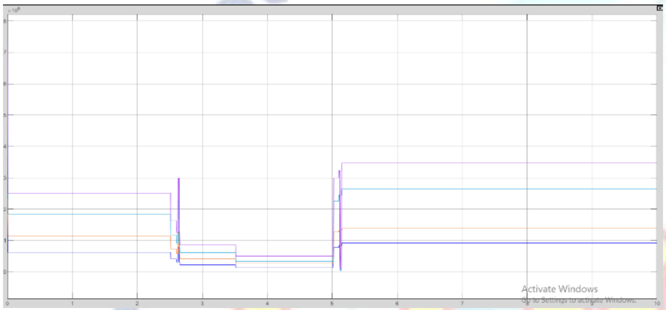

Figure8-The power consumed by HVAC loads

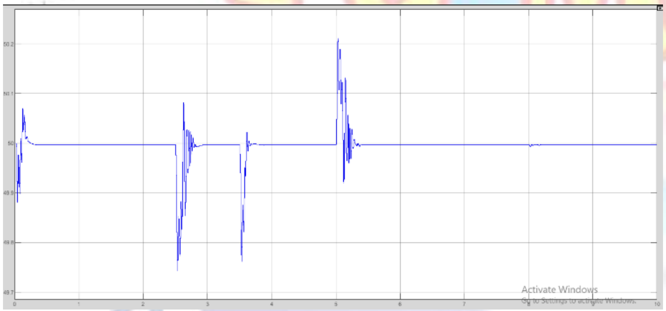

Figure9-The load frequency which is controlled by the above phenomenon

In this, when sudden load changes occurs, the frequency tends to deviate from the rated frequency of 50 Hz. In this, the peak overshoot is around 50.21 Hz and undershoot is around 49.74 Hz.

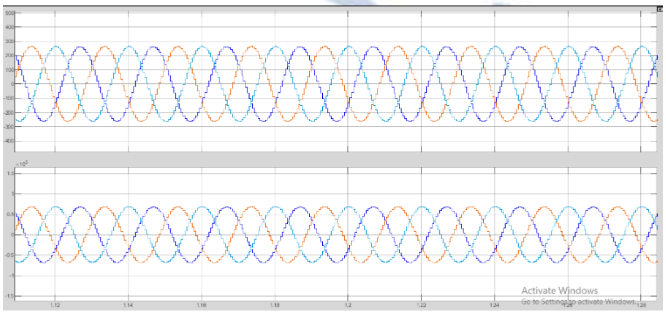

Figure10-The load voltage and current waveforms

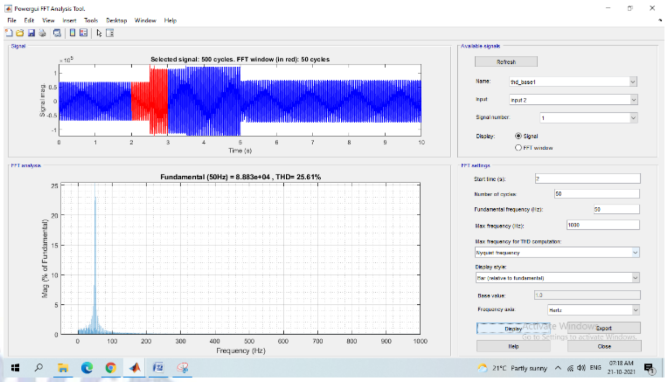

Figure11-The %THD measured from the load current

In this, the %THD is around 25.61% for zone 1.

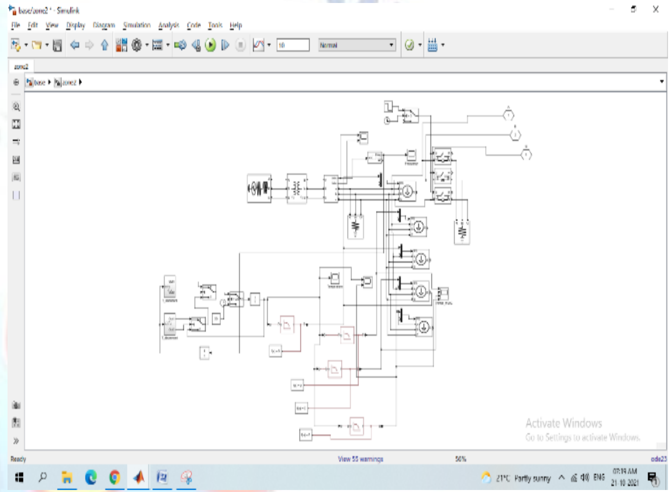

Figure12-The simulation circuit for zone2

In this two loads are connected apart from five HVAC loads. The load1 is connected from t=0 and load2 connects to the system at t=5s. Similarly for zone3 two loads is connected where load1 is connected at t=0s and load2 is connected at t=8s. Due to this there are power flow from one zone to other zone whenever excess loads are connected to that particular zone.

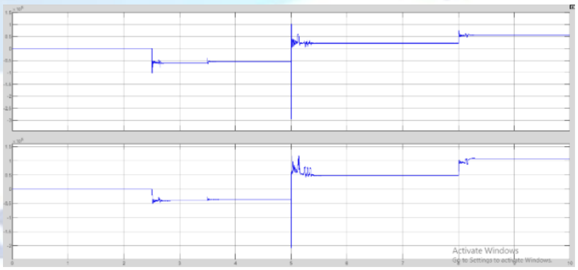

Figure13-The power treansfer from zone1 to other zones

In this, initially there is zero power transfer and when load2 is connected at t=2.5s in zone1, it receives power from other zones until t=5s as the excess loads are disconnected. But in zone2, load2 is connected at t=5s. Hence, there is power flow from zone1 to zone2. And the direction of power flow changes as it stops receiving power and starts transmitting the power at t=5s to other zones.

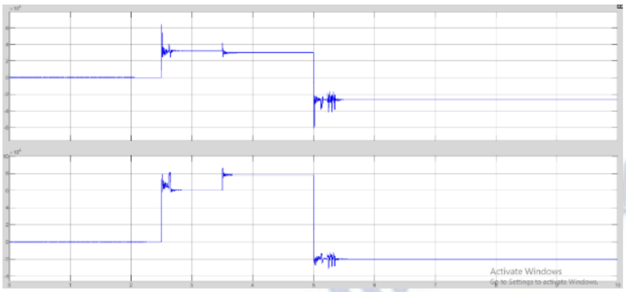

Figure14-The power measured at zone2

In this, the power is transmitted to other zones from t=2.5s to t=5s and when excess load is connected at zone2 at t=5s, the power flow direction is received as it accepts the power from other zones.

Figure15-For zone 3, the power waveforms are shown as above

Here, the direction of power flow changes at t=8s as load2 is connected at that instant.

In this, multi area system, the ann control is introduced in temperature control loop for each zones. By controlling the temperature, the load power consumption is controlled and thereby load frequency is controlled. Hence the input for anncontrol is frequency error whereas the output of the controller is temperature set point of HVAC loads.

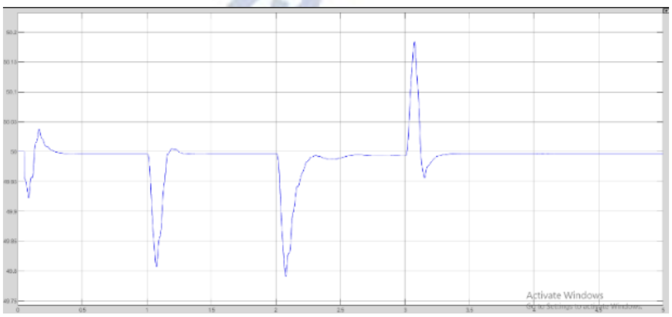

Figure16-The load frequency with ann control In this, the peak overshoot of the frequency is around 50.185 Hz and undershoot is around 49.79 Hz. Similarly the %THD is improved as there are reduced distortions.

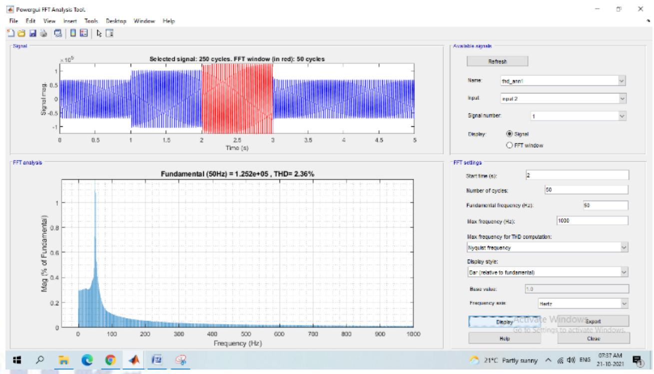

Figure17-The %THD of the load current In this, the %THD of load current is around 2.36% with ann control. It is 10 times lesser than that of the %THD without ann control.

IV. Discussion and Conclusions

We have designed a frequency control scheme and power management algorithm to analyze power flow from lower demand to higher demand area. The 3 Zone-Smart grid system was able to successfully incorporate temperature control scheme, to reduce power consumption and balance the frequency within limits based on simulation and analysis method in the respective loads, thereby reducing instability. Further, the other waveform characteristic values can be measured, compared and can be found to be advantageous. Various overloading phenomenon were observed in 3 zones. Here, we also designed a new frequency control and protection technique at emergency conditions. The operating scheme was successful in controlling the system frequency within the prescribed limits using the HVAC loads connected to certain bus. The studied modified power system includes IEEE9 bus system connected with different types of loads when PID controller is used. Different faults can be analyzed with fuzzy control techniques being dealt with.

In overall in this research paper of thesis, the load-frequency control (LFC) restores the balance between load and generation in each control area by means of speed control. It minimized the transient deviations and steady state error. This paper investigates LFC with time delays using a simple algorithm for primary control and tie line power transmission for secondary control using MATLAB/SIMLINK. Here, Area 1, 2 and 3 are connected by normal AC tie-line. The transmission link is to transfer power over long distance without any frequency deviation. The advantage of incorporating time delays is important for satisfactory dynamical responses. The ANN based controller introduced is found to be very faster compared to analytical method, upon overloading disturbances in frequency. The simulation time, distortion and frequency deviation is found to be improved with the designed system.

V. Future Scope

There may be lot of scope in future and demand for frequency and voltage control in rising field of smart grid'sinnovations. The smart grid mission increases the involvement of customer in the power supplying system. The opportunity of service contributor has been limited in the power transmission and distribution systems across the world. The wish to improve the service quality of the power delivery, system has led to incorporation of new features in the system. Smart grid is consider as the next generation power grid, which supply bi-directional flow of electricity and information, with better power grid reliability, security, and efficiency of electrical system from generation to transmission and todistribution. As smart grid continues to develop, realization of a reliable and stable system is necessary. There is lot of demand in study of different configurations and parameters in this area. The obtained research work can be extended to 'n' no. of zones, as smart grids is finding a rising standard. We can also check possibilities for varying algorithm with 'n' no. of buses in a zone considering different bus system like IEEE9, extending to IEEE33 and more. A unique algorithm is designed here, ANN(Artificial neural network) and ML(Machine learning) techniques are gaining utmost importance due to its tremendous and accurate performance compared to analytical and other controllers like PID, Fuzzy, etc. Different sources can also be incorporated with more complications that could be sorted.

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