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NOVEL APPROACH TO DESIGN IOT BASED INTELLIGENT INDUSTRIAL LOAD MANAGEMENT SYSTEM

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***Abstract*- Today, the internet is evolving to the point where every device in the future can be realised as an internet connected device. The need of the hour is to harness the power of internet to solve the most exciting problems faced by mankind. Traditionally smart grid is one of most advanced application realised by Internet Of Things (IOT). In this paper we take one step further where the electricity generated through cogeneration process at an industry by industrial wastes is used efficiently thus reducing the load on the national grid. This paper introduces a novel approach to integrate IOT with an intelligent Industrial Load Management System. A virtual control system is designed to balance the supply of electricity on the network with the electrical load of an industry by recovering heat from hot chemical gases to produce electricity and by disconnecting the low priority loads automatically during power shortage periods. This approach takes advantages of the LabView's better hardware support, rapid configuration, MATLAB's ability to perform complex calculations and newer innovations helping in cheaper ways of realising internet connected devices. An intelligent power generating system which works on waste heat recovery mechanism comprising a boiler turbine system is modeled using MATLAB and a human machine interface is developed using LabVIEW. The system that is modeled in MATLAB can be simulated by LabVIEW Simulation Interface Toolkit (SIT) toolkit. The SIT provides a seamless integration between MATLAB/Simulink and LABVIEW. With its pure software oriented real time digital simulation and minimal hardware components involved this method can be implemented with minimal cost and can be easily extended further.**

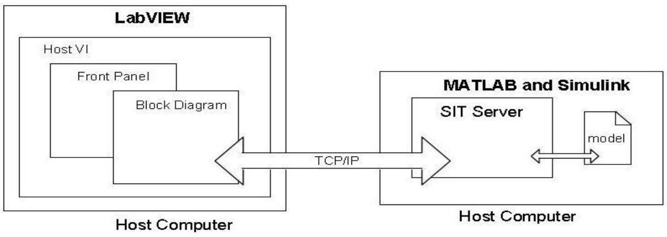
I. Introduction

Load Management is the process of balancing the supply of electricity on the network by adjusting or controlling the load rather than the power station output. An important problem of the society is the increased demand for electrical power. For the most part electrical utilities have relied on volunteer cooperation from individuals and industry to reduce power consumption. However the capacities of power generation facilities being more frequently strained to the point of causing occasional black outs substantial attention has been given to find an efficient load management system.

A. Simulation Interface Toolkit (SIT)

The Simulation Interface Toolkit (SIT) provides a way to create a LabVIEW user interface that is used to interact with a Simulink model. With a LabVIEW user interface, the model parameters can be manipulated and output data of the Simulink model can be viewed immediately. For LabVIEW to communicate successfully with Simulink, MATLAB must be running at all times. When MATLAB is launched, Simulation

Interface Toolkit (SIT) Server is started automatically, which enables LabVIEW and MATLAB to communicate with each other. Below Figure represents the communication between LabVIEW and MATLAB/Simulink through TCP/IP.



B. Example of an industrial load management system

The simple setup as shown in Fig. 1. is used to explain a load management system. A The heat from the Waste Heat Recovery Unit (WHRU) is used to recover heat from hot chemical gases produced in the industry to heat the water and produce steam which when passed through the turbine generates electricity. If the electric load in the industry increases the actual rpm of the turbine decreases, the difference between rated rpm of the turbine and actual speed of the turbine is fed to the Proportional Integral Derivative (PID) controller which allows more steam to pass at the input with the help of a control valve, which in turn increases the speed of the turbine and finally the actual speed of the turbine reaches a steady state value. If the load on the network decreases the actual rpm of the turbine increases, the difference between rated rpm of the turbine and actual speed of the turbine being negative allows PID controller to close the control valve to limit the steam flow, which in turn decreases the speed of the turbine and finally the actual speed of the turbine reaches its steady state value. Thus the speed of the turbine is maintained at its rated rpm to produce electricity by recovering heat from industrial chemical gases and hence reduction in dependency on the national grid. The power generated by this process can be typically up to 3 MW, thus reducing the power taken from the national grid by 3MW. The communication between the industrial load management system and the national grid can be established by machine-to-machine communication which forms the basis of IOT.

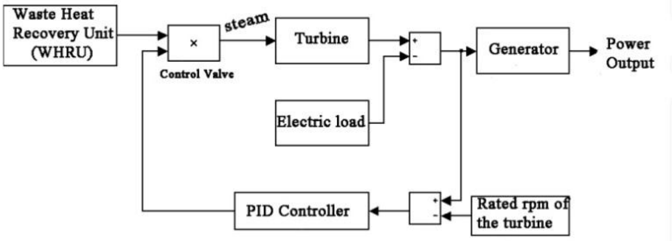


Fig. 1.

As generation and consumption of electricity is dynamic in nature, the electricity produced should be consumed immediately after its generation. Researchers are always looking either for alternate sources of energy or to developing energy efficient appliances. A lot of time and money is being invested in such research activities and they are successful to some extent. In spite of all these developments, there are power outages in some countries due to power shortage. Hence it is a good idea to automatically switch off low priority loads during power shortage periods and transfer the power to the areas which suffers from power outages. However the priorities itself may be dynamic. The dynamics of priorities of the electrical appliances may depend on the season, the time of the day or comforts of the person. For example, during day time electrical lights may not be as important as air conditioners in offices, during winters electric fans may not be as important as they are in summer. So, the concept of disconnecting low priority loads can be fruitful under over load conditions. However, every industry has its own priorities hence they have to be defined by the users. This concept can be extended to domestic purposes as well by integrating this solution with the existing home automation systems.

To understand this concept better, let us take a simple model of an industry that generates a constant power output of 3 MW internally by WHRU mechanism. Since the industry itself can produce 3 MW of power through WHRU, the power required to be taken from national grid falls by 3 MW. Let us assume that a load of 10MW is considered as an overload condition. If the load on the electric network reaches 10 MW then a load management process should come into action which disconnects low priority loads automatically until again the total electrical load on the network falls below 10 MW. Table 1 shows the possible situations that may arise. Electric load of the industry is represented by L, Power generated from the WHRU by W, Power taken from the national grid by N.

Electrical load of the industry (L) (in MW)	Power generated from the WHRU(W) (in MW)	Power taken from National Grid (N) (in MW)	Disconnect low priority load
L=0	W=0	N=0	Not required
L<3	W=3	N=0	Not required
3<L<10	W=3	N=L-W	Not required
L>10	W=3	N=7	Yes

TABLE 1. Possible situations that may arise during load management process.

II. Simulink Model of a Boiler Turbine System Connected to a WHRU

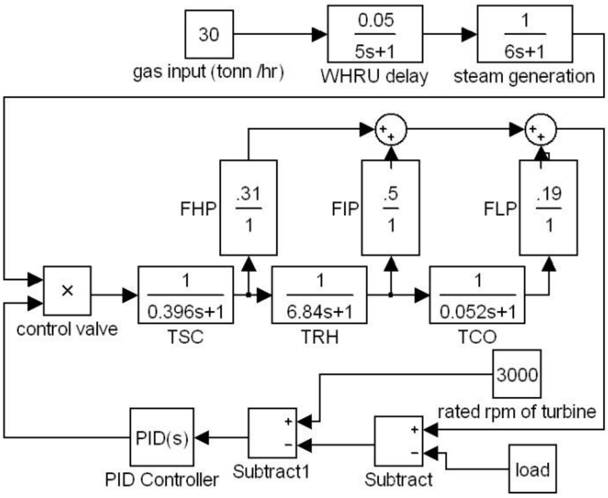


Fig. 2. Simulink model of the boiler turbine system connected to WHRU

A. Adjusting valve position depending upon load

Fig. 2 shows the Simulink model of the boiler turbine system connected to a WHRU. The rough estimates of the system are considered and included in the model. For any practical boiler turbine model system, the process of deriving the parameters of these parameters is clearly explained in Ref. [1]. In the Simulink model developed, the hot chemical gas input is taken to be a constant 30 ton/hr. The rated rpm of the turbine is assumed to be 3000 rpm. The gas enters the WHRU modeled as a time delay with a delay of '5 sec' where heat is recovered. The steam generation block generates steam and the flow of the steam into the turbine is regulated by a control valve whose position is controlled by a PID controller. The so produced steam is sent through the turbine section which has three subcomponent turbines High pressure turbine, Intermediate pressure turbine and the low pressure turbine respectively. TSC, TRH and TCO represent steam chest, reheater and crossover time constants respectively. FHP, FIP and FLP represents the fractional part of the heat produced by the High pressure, Intermediate pressure and Low pressure turbines respectively. The electric load applied reduces the speed of the turbine from its rated rpm of 3000 rpm, the increase in the load is fed back to the system and the valve is further opened allowing more gas to enter the turbine section which results in increase in the speed of the turbine and hence increase in the generated power to satisfy the load.

If the load on the network decreases the speed of the turbine increases from its set point of 3000 rpm, this decrease in the load is fed back to the system and the valve is regulated to limit the amount of steam entering the turbine section and consequently reduction in the speed of the turbine until it again reaches its steady state value of 3000 rpm. Hence the speed of the turbine is always maintained at its rated rpm. However it is to be noted that the maximum power produced from this process is typically around 3 MW, the remaining load should be satisfied by taking power from the national grid.

B. *Disconnecting low priority loads under overload conditions*

When the electric load on the industry crosses its maximum limit of 10 MW, then a method of disconnecting the low priority loads is required. To achieve this, the loads itself have to be prioritized and the priorities have to be reviewed once in a while. Once the priorities are assigned, the system does its task of disconnecting the loads with the help of feedback received from MATLAB and LabVIEW software

III. Process of Disconnecting the Loads Under Overload Condition

The loads are given four priority numbers ranging from 1 to 4 with priority 1 being highest. These priorities are dynamic and can vary from time to time. Under overload conditions, loads with priority number 4 are disconnected initially and the remaining load is checked for overload condition. If the remaining load is still causing overload condition, then loads with priority number 3 are disconnected and the process is carried out till load falls within the limits. The process of disconnecting loads during overload conditions is explained with the help of snapshots taken during the simulation process considering all the four cases outlined in table 1

Case 1: When the load is zero, i.e. when the industry is shutdown, then the power generation from WHRU is halted and no power is taken from the national grid. Fig 3 shows such a condition. Moreover, slide1, slide2, slide3 and slide4 represent the loads with priority1, priority2, priority3 and priority 4 respectively. Indicators Boolean, Boolean 2, Boolean 3 and Boolean 4 represent the status of loads with priority1, priority2, priority3 and priority 4 respectively.

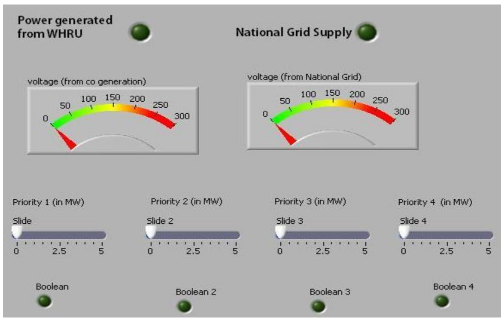


Fig. 3. Case 1 LabVIEW user interface under no load condition

Case 2: When the load is below 3 MW, the required power can be generated from WHRU turbine boiler system and the no power is taken from the national grid. Taking an instance from the simulation process, Fig 4 represents that the load with priority 1 is 0.50505 MW, priority 2 is 1.0101 MW, priority 3 is 1.0101 MW and priority 4 is 0.2525 MW. Hence the total load sums to 2.7777 MW which is below 3 MW. Hence there is no power taken from the national grid and the power generated from WHRU boiler turbine system alone is sufficient to run the load.

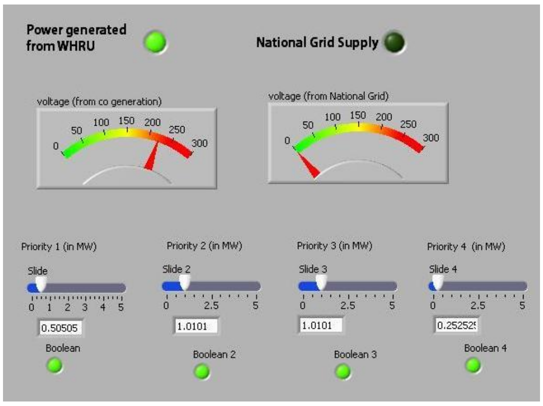


Fig. 4. Case 2 When the load is below 3 MW

Case 3: When the load is between 3 MW and 10 MW. In this case 3 MW of power is generated from the WHRU boiler turbine system and the remaining power is taken from the national grid. For example Fig 5 represents that the load with priority 1 is 2.0202 MW, priority 2 is 1.0101 MW, priority 3 is 5 MW and priority 4 is 1.5151 MW. Hence the total load sums to 9.5454MW which is between 3 MW and 10 MW. In this case 3 MW is generated from WHRU boiler turbine system and the remaining 6.5454 MW is taken from the national grid

Case 4: When the load is above 10 MW which implies that the system is in overload condition. Now the load management system designed acts and starts disconnecting the low priority loads until the load become less than 10 MW so as to avoid

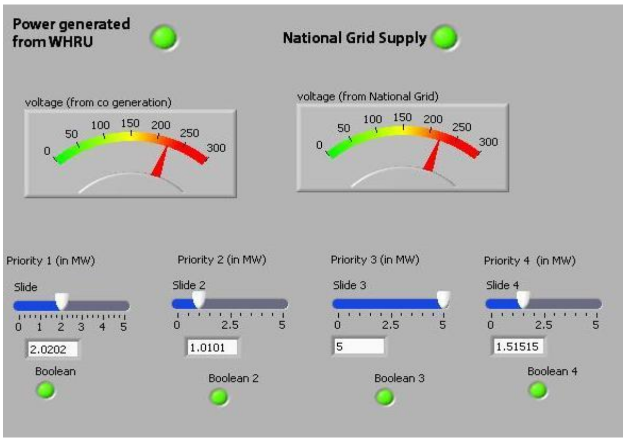


Fig. 5. Case 3 When the load is between 3 MW and 10 MW

overload condition. For example Fig 6 (a) represents that the load with priority 1 is 4 MW, priority 2 is 3 MW, priority 3 is 2 MW and priority 4 is 1.5 MW. The total load sums to 10.5MW which indicates overload condition. Hence the load management system designed checks the possibility of disconnecting the loads with priority number 4 to eliminate the overload condition. In this case by disconnecting the 1.5 MW load (priority 4) the total load become 9MW which is below 10 MW and hence overload condition is eliminated. Out of the 9 MW, 3 MW is generated from the WHRU boiler turbine system and the remaining 6 MW is taken from the national grid.

Fig. 6. (a). Case 4 When the load is above 10 MW

In Fig 6 (b) load with priority 1 is 4 MW, priority 2 is 3 MW, priority 3 is 4 MW and priority 4 is 1.5 MW. The total load sums to 12.5 MW which indicates overload condition. Hence the load management system disconnects load of 1.5 MW (priority 4) and checks for overload condition. Since the 1.5 MW load is disconnected, the load becomes 11 MW which is clearly greater than 10 MW. The load management system now disconnects the 4 MW load (priority 3) which has least priority among the remaining three loads. Now the load becomes 7 MW which is less than 10 MW. In this way, disconnecting low priority loads using MATLAB and LabVIEW can be achieved during overload conditions

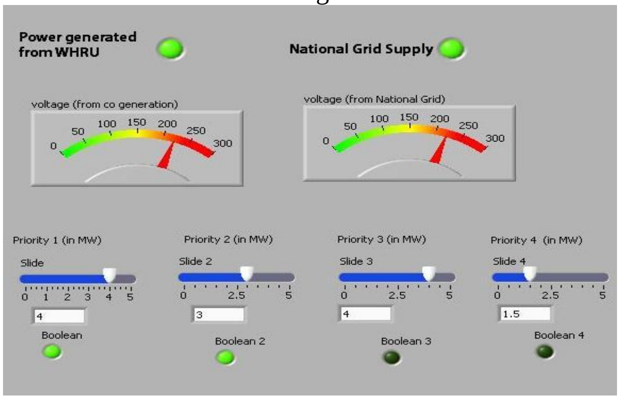


Fig. 6. (b). Case 4 When the load is above 10 MW

IV. CONCLUSIONS

The steam input to the turbine is controlled using MATLAB/Simulink and LabVIEW through data exchange between them with the help of SIT toolkit. The industrial load management system designed disconnects low priority loads during overload conditions periods. This data is transmitted to national grid to transfer the excess electric power to the needy areas. Even though this is designed for an industry, this concept can be extended to domestic purposes as well by integrating with the existing home automation sytems. The LabVIEW's DAQ assistant can be used to control the switches of the load (ON or OFF) physically. The data exchange between LabVIEW and MATLAB/Simulink can also take place with the help of OPC server and OPC client concept.

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