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Enhancement of Sensor for Load Frequency Control and Fault Detection in Power Systems

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Abstract:- In modern day power systems there are frequent variations in load which results in undesirable change in frequency. Sensors are being used to observe the variations and restore the frequency. But the design of sensor is mostly restricted to conventional engineering techniques. Conventional sensors have low degree of sensitivity and therefore have poor robustness. Here, an attempt is made to develop a sensor for fault detection and its isolation for load frequency control in power system using model based design approach. The purpose is to monitor from external end smart operation of controller for load frequency control in power system. The outcomes of sensor may be implemented on controller for load frequency control unit in power system. Also the change in frequency due to changes in load can be controlled to restore normal frequency by applying the sensor output to the controller which in turn controls fuel supply and therefore frequency in load affected power system.

I. INTRODUCTION

The concept of application of sensor for load frequency control was first implemented seventy years ago. But the application of sensor in bringing together with problem specific controller, started by the seventh decade in early days and even today the design of sensor is mostly limited to conventional engineering techniques. To overcome lag-lead and mismatch in conventional sensor technology [5], the design approach has been shifted to model based design of sensor. The sensor developed on this theory had the great strength of including all the requirements of the model which was to effectively and smartly control the dynamics of controller [7]. The earlier techniques did not posses this feature. The most important characteristics of sensor viz. fault detection and fault isolation needed to be executed not only with all the robustness but with assured outcome.

In order to develop the desired sensor, it is planned to recognize mathematical representation of sensor and load frequency control in a power system [10]. A state-space model to be obtained for the sensor and load frequency control in a power system for the state space equations [11]. Then unknown inputs sensors and actuators have been obtained [14]. In order to simulate state space model MATLAB programming is used. In the end, testing of fault detection and fault isolation for Sensor, Actuator, Sensor and actuator together is performed. The results of these tests will facilitate load frequency control and frequency restoration in power system.

II. THEORY OF FAULT DETECTION AND ISOLATION

A fault detection system, depending on its performance, is called FD (for fault detection) or FDI (for fault detection and isolation) or FDIA (for fault detection, isolation and analysis) system, whose outputs are correspondingly alarm signals to indicate the occurrence of the faults or classified alarm signals to show which fault has occurred or data of defined types providing the information about the type or magnitude of the occurred fault. The model-based fault detection technique is a relatively young research field in the classical engineering domain technical fault detection; its development is rapid and currently receiving considerable attention. In order to explain the essential ideas behind the model-based fault detection technique, we first give a rough classification of the technical fault detection technique, as sketched in Fig.1

A typical type of control system, which is consists of actuators, Sensors and a process to be controlled. Residual signal is generated such that signals are decoupled from the disturbances (unknown inputs). That means the generated residual signals will only be influenced by the faults. In this sense, such a residual generator also acts as a fault indicator. It is often called unknown input residual generator.

Actuators are used to generate the desired inputs in order to control the process to behave as expected, while sensors provide all the measurements needed for computing the desired inputs and for monitoring the system. A practical control system is designed in such a way that the desired performances can be achieved when all actuators, all sensors, and all components of a process work normally. Unfortunately, no real control systems are free of faults. In fact, Actuators, Sensors, and the components of a process in any control system may be faulty. Throughout this thesis, a fault is defined as any change in an actuator, sensor, or process parameters that lead to any undesired system performances (Excluding a complete breakdown of the control system, which is defined as a failure).When actuator faults occur, the faulty actuators are no longer able to generate the desired control inputs. Some examples of actuator faults are damage in bearings, deficiencies in force and momentum, defects in gears, aging effects, and stuck faults. When sensor fault occur, correct measurement needed for computing control inputs. Typical examples of sensor faults are scaling errors, drift, hysteresis, dead zone, and contact failures. When some components of the process are faulty, the original process has changed in to a different process so that the controller designed for the original process is no longer able to achieve the expected system performance.

Faults can lead to production deterioration or damages to machines that not only cost a vast amount but can also lead to disasters that claim both property and human life. Therefore, the detection of these kinds of faults for Reliability and human safety in modern control system is very necessary. The research on fault detection has attracted many researchers from industries as well as universities [14], and interest in research field is still increasing [20].

An interconnected power system, which is composed of two or more areas, area-wise decentralized load frequency control (LFC) is an effective method of maintaining system‟s frequency and power interchanges. A fault in the implementation of LFC, such as a fault in the measurements of required system variables, e.g., frequency, tie-line flows, unit MW loadings, or a fault in telemetering of these signals, or a fault in the actuators or controllers may result in undesired performance including inadvertent large deviations in the system‟s frequency, power interchanges or loadings of generating units. Therefore, the detection and isolation of these kinds of faults is very important. Fault detection can be treated as observation problem, which has two main stages, residual generation by mean of an sensor and decision making. The problem of designing an sensor for known and unknown inputs has been studied for over two decades [2]-[29]. Model based FDI is the detection, isolation and characterization of faults

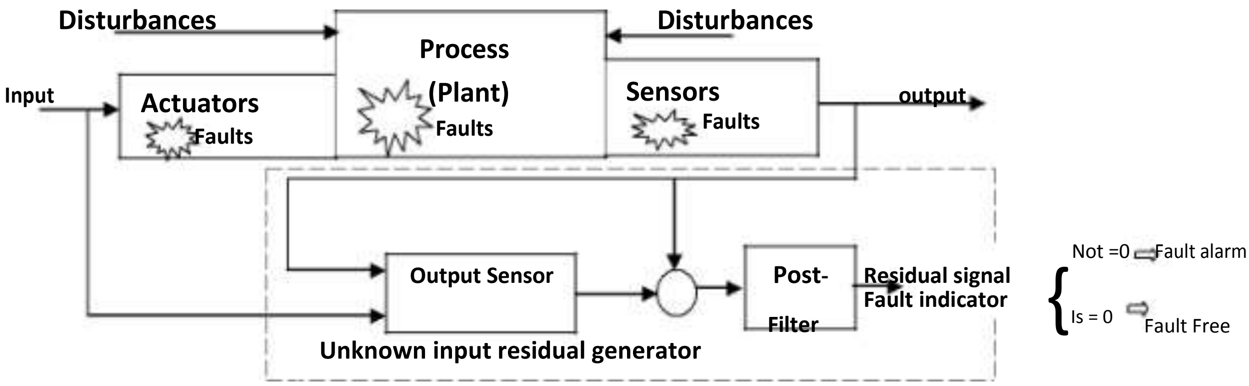

Fig.1. Schematically Description of unknown input decoupled residual generation

based on the comparison between system‟s available measurements and a mathematical model of the system [34]. The unknown input sensor should be designed such that the generated residual signal, which indicates faulty conditions, is insensitive to the disturbances. Decision making may include simple threshold tests or a method of statistical decision.

III. SENSOR DESIGN AND SIMULATION

Model based theory posses the merit of being more close to reality and uses the concepts soft computing rather than the theory of hard computing. It takes into consideration the influencing parameter as expressed in linguistic mode. The other methods provide an sensor which lack robustness and stable operation of the component and sensor. The fundamental approach of assuming the system to be nonlinear by nature and adaptive control strategies yield a more reliable approach for sensor design w.r.t. the competitive approaches such as sliding mode, parity space, classical and plausibility approaches. Further this theory has been one of best advanced version of sensor design. It however requires to develop mathematical model load frequency control in power system.

The frequency of a power system is dependent on real power balance. A change in real power demand at one point of a network is reflected throughout the system by a change in frequency. Therefore, system frequency provides a useful index to indicate system generation and load imbalance. Any short-term energy imbalance will result in an instantaneous change in system frequency as the disturbance is initially offset by the kinetic energy of the rotating plant. Significant loss in the generation without an adequate system response can produce extreme frequency excursions outside the working range of the plant. The control of frequency and power generation is commonly referred to as load–frequency control (LFC) which is a major function of automatic generation control (AGC) systems.

As shown in figure.2, the speed governor senses the change in speed (frequency) via the primary and supplementary control loops. The hydraulic amplifier provides the necessary mechanical forces to position the main valve against the high-steam (or hydro-) pressure, and the speed changer provides a steady-state power output setting for the turbine

In this model we use the simple time delay transfer functions for response of the speed governor, turbine and exciter.

IV. SIMULINK FOR SENSOR AND LOAD FREQUENCY CONTROL

The UIOs that are designed for sensor faults, actuator faults and both sensor and actuator faults generate the residuals such that the detection and isolation of the faults in the sensors and the controllers can be performed.

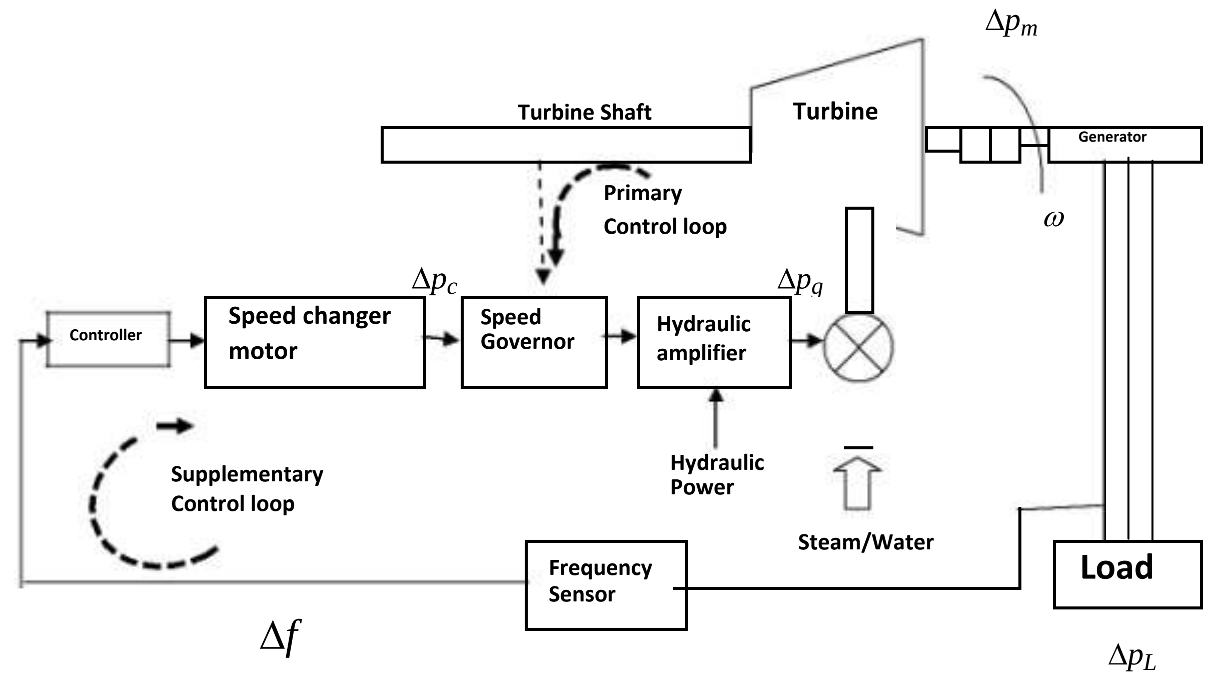

Fig.2. Schematic block diagram of a synchronous generator with basic frequency control loops

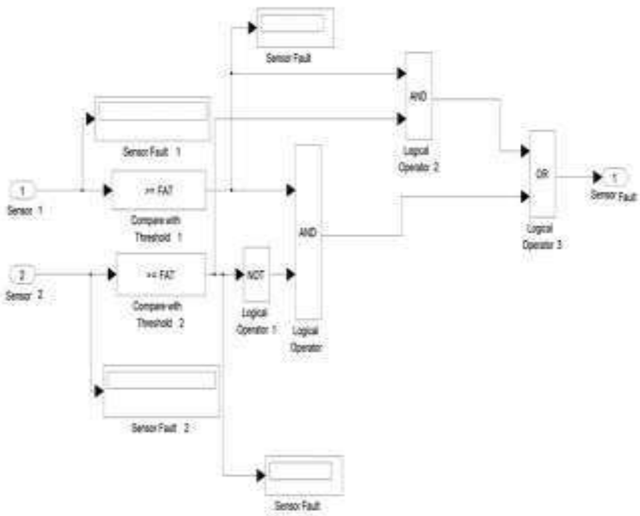

Fig.3. Internal construction of sensor fault logic

The successful designs for the UIOs are robust to the unknown disturbances, which are the changes in the load demand in power system control areas.

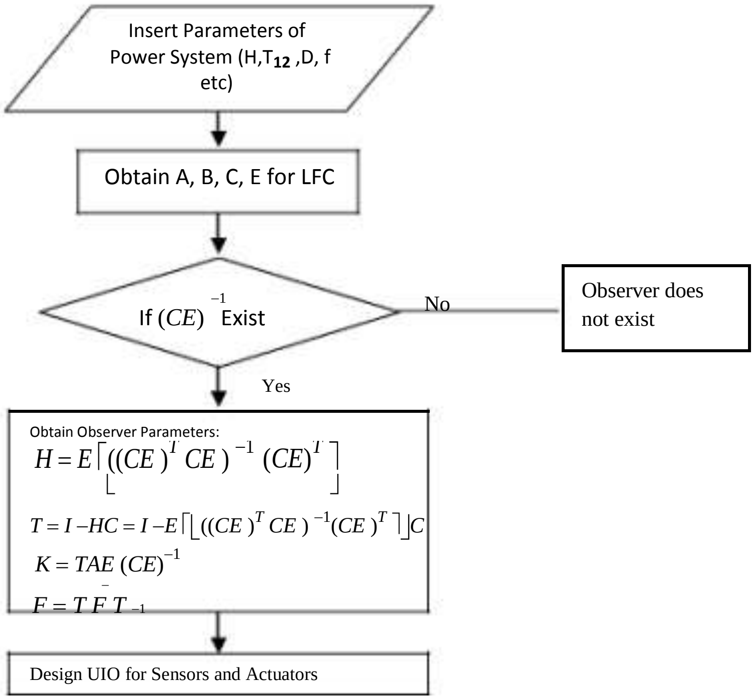

Fig.4. Flow Chart for Design of Integrated Model for Observer and LFC

In the proposed sensor, power system parameters such as change in frequency, tie line power flow, generated power etc is fed.

By using these parameters, input variables will be calculated namely A, B, C, E. It will check for a condition, if this condition is not satisfied then the sensor will remain unresponsive. If the condition is satisfied i.e. the existence of a CE^{-1} , then by obtaining observer parameters it will check weather the fault is in the sensing element, controller or actuator. After detecting the faulty section it will send signal on the basis of severity of fault. By giving alarm or by disconnecting the faulty section.

A. Testing of group

In this section, the design of the method to be applied considers the possibility of existence of both

Types of faults.

Case 1: Existence of UIOs

To fulfil the requirement for the existence of the all UIOs designed for both types of faults, the set of measurement variables has to be selected such that for sensor FDI and for actuator FDI. The model implies that the set of measured variables is $y = \begin{bmatrix} \Delta f_1 & \Delta f_1 & \Delta P_{tie} & \Delta f_1 + \Delta f_2 & \Delta X_{gv1} & \Delta X_{gv2} & \Delta P_{g1} & \Delta P_{g2} \end{bmatrix}'$.

Fig.5. shows the successful FDI in sensor -1 and actuator-2 and isolation can be seen in both changes in frequency and governor valve position.

Although the existence of UIOs is guaranteed with this set of measurements, our simulation results show that the faults in sensors and actuator measuring can be detected and isolated successfully. Fig.4 and Fig.6 illustrates the unsuccessful detection and isolation of a fault in the actuator and sensor measuring.

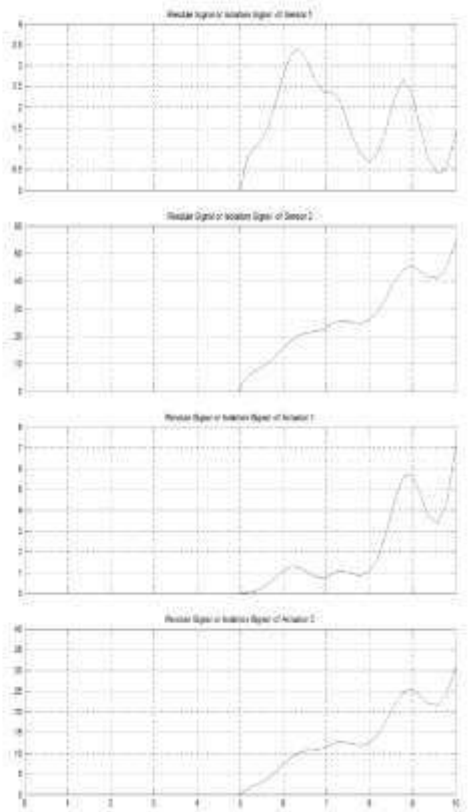

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Fig.5. Error Signal of System Parameters for Isolation in in sensor -1 & Controller

To obtain complete success in sensor and actuator FDI, the set of measured variables is selected as

$$y = \begin{bmatrix} \Delta f_1 & \Delta f_1 & \Delta P_{tie} & \Delta f_1 + \Delta f_2 & \Delta X_{gv1} & \Delta X_{gv2} & \Delta P_{g1} & \Delta P_{g2} \end{bmatrix}'.$$

The enhancement in the set of measured variables provides complete success in the detection and isolation of any sensor or controller fault. Fig.7 and Fig.8. Illustrates the successful detection and isolation of a fault in the sensor measuring and controller area 1 and 2.

Successful isolation of the sensor and controller faults that are occurring at t=5s. It should also be noted that the proposed procedure is successful in isolating the faults occurring at the same time, which is considered in this work.

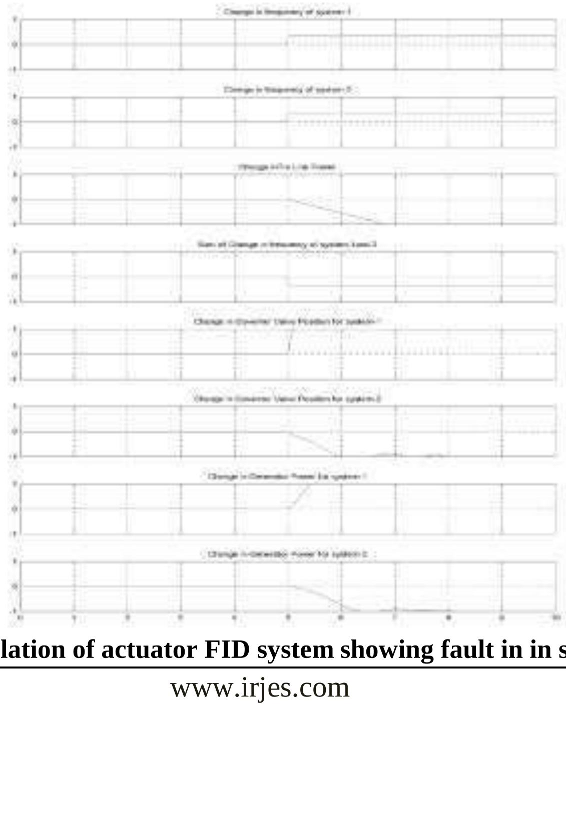

Fig.6. Signal for Isolation of actuator FID system showing fault in in sensor -1 & Controller

V. CONCLUSION

The basic aim to develop a monitoring system for effective and smart operation of control system could be met by way of developing a sensor for load frequency control in a load demand based power system. Model based sensor design approach has proved successful in applying the sensor over a load frequency control in power system. The system is adaptive to all the variations taking place in load due to model based approach, the implementation of sensor has proved to be more smarter. The state space model based on differential equations representing the sensor and load frequency control has been used to develop Simulink for development of sensor.

The outcomes of sensor may be implemented on controller for load frequency

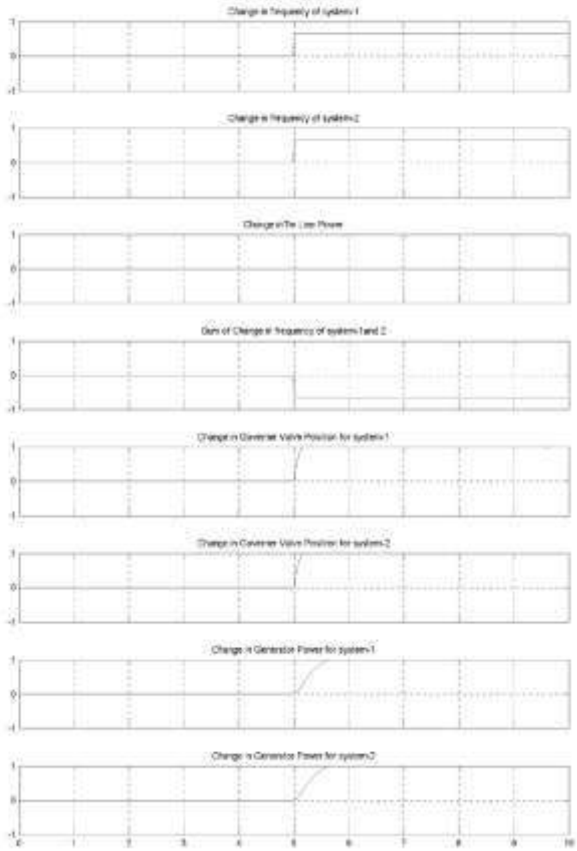

Fig.7. Signal of System Parameters for Isolation in both Sensors and Controller

Control unit in power system. Also the change in frequency due to changes in load can be controlled to restore normal frequency by applying the sensor output to the controller which in turn controls fuel supply and therefore frequency in load affected power system. It is possible to develop real time model for the proposed problem.

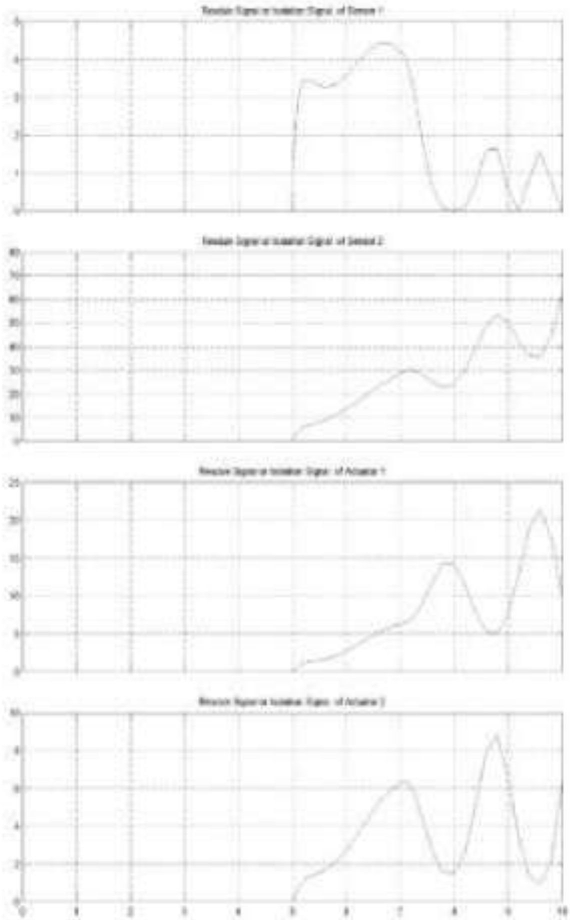

Fig.8. Residual Signal for Isolation of actuator FID system showing fault in both Sensors and Controller

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