Automatic Load Balancing and Fault Tolerance in a Client Server Model Based Integrated Substations

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Abstract— In this paper, we present a novel design for software-based fully automated control station in the integrated substations environment. The idea is, to enable all the substations to communicate with control station as well as with other substations through computer network. The communication is based on client-server architecture. Control station is behaving as the server and substations are behaving as the clients. The scenarios we are taking into the consideration include automatic load balancing and automatic fault tolerance. This model for integrated substations drastically reduces the time latency if compared with traditional model. It reduces the time as well as human intervention in the critical tasks such as responding on some fault, load balancing actions, etc. The proposed model is fast, scalable, flawless, robust and transparent as it is using the capabilities of computers and networking in between them.

Keywords—Integrated substation, Automatic load balancing, Fault tolerance.

I. Introduction

With the concept of integrated substations, the demerits of traditional substations can be removed. With the idea of integrated substations, less hardware cost and increase reliability can be obtained [1]. Integration of the substations can be done by employing the use of intelligent control units, merging units, via optical fiber. Also different protection, control and metering units are used. These devices are capable of converting the analog data in to digital form. The next step to automate substations is to develop the appropriate data communications network (Wide area network). The main purpose of the paper is to present the communication model between the control station and the substation as well as peer to peer communication in between the substations. This communication is implemented with the help of the client server based model. With the help of client server model, load can be balanced in the different substation as well as fault conditions can be detected easily.

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Client server model also provides protection against the occurring fault in the substation. This model has many advantages as it reduces the cost of hardware connection while providing the fast, convenient protection, and data transfer capability. Main focus is on real time information i.e. the state of the substation can be obtained at any instant. Hence, this increases the overall reliability of the substation.

This paper includes the study of following, as listed below:-

(1) In this paper, we study the digital technology used in station (WAN or internet) communication network, which is developed to integrate the protection, control and data acquisition,

(2) In addition, this paper proposes a client server model to balance the load and fault tolerance between different substations. It includes control station which has been taken as server while different substations are treated as clients, thus with the help of client server technology the communication between different station will be done in a fast effective way.

II. Traditional Substation

In traditional substation, Protection and control is based on set of a standalone subsystem as shown in fig.1. Substation is under remote control from the control station but the limited information can be obtained. The whole information related to any disturbance or damage in the equipment of the substation can be obtained at the station itself. The standalone subsystem has the inherent redundancy of data transmission and control circuits [3]. Each subsystem has different input and output circuits. Thus, requires lots of long wires more than in thousands to connect different power apparatus, to relays, circuit breaker and to other equipment at the control station. And these wires are also distributed around the switchyard.

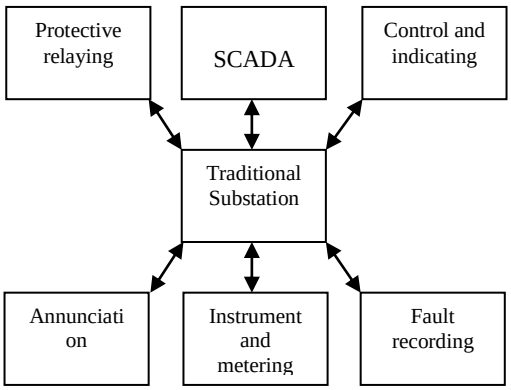

Figure 1. Traditional substation monitoring, protection and control [2]

Within the control station, switchyard may be connected to equipment like CT's, which may be connected to ammeter, relays, oscilloscope, transducers for the supervisory control and data-acquisition (SCADA) [6]. Cables are installed with particular length or size according to the requirement. Once cables are installed in the traditional substation then it is difficult to make any further modification. This modification occurs in the case where cables become old and insulation starts failing. The interfaces between the different devices that need to be covered by the cables are affected by the phenomena of electromagnetic transient, which results in failure of the equipment or other damages [1].

III. Prior Work

After traditional substations lots of achievements have been made which has led to a fast integrated substation. These integrated substations are different from the previous traditional substation. The new integrated substation does not require long wires for its interconnection between the equipment. The concept of using different cables which are cut into specific lengths according to its use in traditional substations has been demolished [1]. With the use of integrated substation the complexity of the substation has been reduced. Capital and operating cost are low with integrated substation. Reduce control room space is obtained and it eliminates the equipment that are redundant. This is possible with the use of modern microprocessors, digital signal processing technique, optical transducers and fiber optic communication technique. In integrated substation, initially analog information is converted into digital information and then they are multiplexed into Intelligent Electronic Devices (IEDs) with the use of fiber optic connections. This digital information is subjected to the microprocessor where decisions are made in the protection and control algorithm. IEDs have the advantage of exchanging operational and non-operational data over the same communication channel. Thus, IEDs replaces the hardware interface between devices through communication link. It helps in improving the reliability, maintenance, life extension and planning. This digital communication is based on IEC61580 protocol [1].

Hence, with the help of integrated substation the real time information of the state of the substation can be obtained easily [1]. These integrated substations are fast in operation in response to any fault or disturbance in the substation and corresponding protection can be taken up.

IV. Client Server Model Based Integrated Substation

Recently, there has been a vast improvement in the field of networking technology, which is now an advantage for power system automation among the substation. Technologies such as Ethernet, TCP/IP, LAN (Local Area Network), WAN (Wide Area Network) has led to a new trend of integrating substation. These modern technologies can be taken into advantage by incorporating their capabilities while designing the communication channel between the substations [6].

In this paper, we have presented a novel approach by developing a client server based integrated substation for automatic load balancing and fault tolerance. This is done by making control station as server and different substations as clients. Interaction between the control station (server) and substations (clients) is established by using socket programming. This way the effective communication can be made between control station and substation as well within the substations which is also called peer to peer communication.

A. Client Server Model

Client Server Model is a computing model which is referred to the two processes or the two applications which communicate with each other to exchange information. One of the application acts as a server and the other application acts as a client. A server is a host and Client is the one which request's the server content or server functions

- Client – A Client is a single user process which makes a request for the information. After request is being processed then the process may either terminate or do some other processing. Client actively initiates contact with the server and can access multiple services as needed.

For example: Internet Browser works as a client process which has a function to send the request to the Web Server to get HTML web page.

- Server – A server is a one or multi user process which takes the request from the client. After getting request from the client, server does further processing as per the request and then respond to the client accordingly. Once this is done it becomes ready to serve another client. Server accepts each request from client but offers single service. Servers are always alert and ready to serve incoming request from the client.

For example: Web server waits for the request from the Internet Browsers. And as soon as it gets request, it picks up the requested HTML page and send it back to Browser [11].

Two types of client server architects -:

(a) 2- Tier Architect - In the 2-Teir Architecture direct interactions takes place between client and server. It has simple structure and easy to maintain. But this may have some security problems. Like in case, if the clients send several requests then it may cause data integrity problem.

For example: - Internet explorer and web server. In this using Secure Socket Layer (SSL) security problems can be sort out [12].

(b) 3-Tier Architecture - In 3-Teir an extra layer has been introduced in between client and the server. This extra layer is called middleware. Middleware's function is to check security and to provide balance in load in case of any heavy loads. All requests are sent to the middleware from the client. Middleware does the required authentication after that it passes the requests to the server. Then, server does further processing and respond to the middleware accordingly and then middleware passes the response to the client [11]

For example: - web sphere is the middleware between **web** server and web browser.

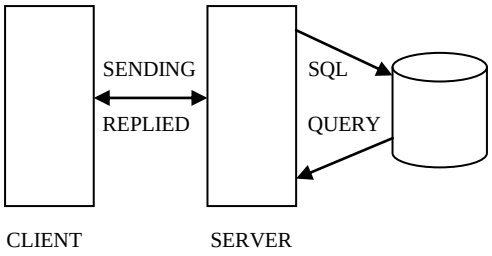

Figure 3. 2-Tier Architecture.

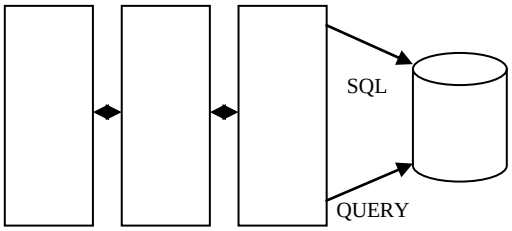

Figure 4. 3-Tier Architecture.

B. Socket Programming

Sockets are a protocol independent method of creating a connection between application process and the transport layer. In other words we can say it is the method of sending or receiving messages to/from with another computers using standard UNIX file descriptor. In client server application framework UNIX socket can be used.

Use of sockets:

(a) Connection: Communication is based on client server model in which server waits for the connection request from the clients. Server accepts the request and then connection is established.

(b) Connectionless: In this peer-to-peer communication takes place, i.e. it doesn't require a connection instead the sender in each message specifies the destination address [12].

C. Algorithm for substation communication

Below are the steps shown in the form of a flow chart (fig. 5).It shows how the communication is established between control station (server) and substations (clients) as well within the substations (clients) with the use of socket programming

V. Results and Discussion

In this paper, fully functional automated software based control system has been proposed. A demo running model of integrating substation has been introduced on Linux operating

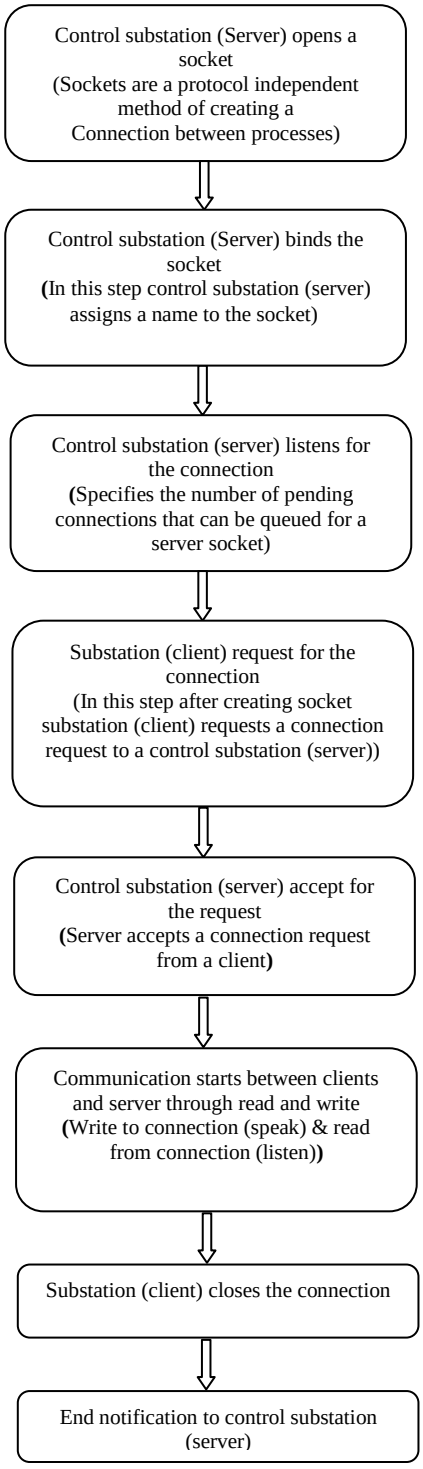

Figure 5. Flow chart of substation communication

system with the help of socket programming. This includes a control station (server) and substations (clients).This demo model has been designed for n number of substations (clients). Initially control station is created and then different substations are created. And then the communication is established between the control station and the substations. Initially control station is opened and then the substation is opened, the information of substation being opened is sent to

the server. When further substations are opened then the information of the state of the substation of being opened is sent to the server as well as to the previously opened substation.

Note- if any substation turned down then its information is sent to the control station as well to each of the other substations. If a control station is turned down due to some reason then such situation the respective substations will automatically turned down.

In fig 6, the behavior of control station (server) is shown; it shows the scenario in which different substations are opened. The information of the state of the substation can be obtained at the control station. In fig.6, when substations (clients) 4, 5 and 6 are opened, their running status information is present at the control station. Fig 7 shows how substation operates when it is opened. The entire parameters like SHOW, CAST, NUMERIC SUBSTATION, LDEXCD, VOLDROP, DONE and HELP are displayed on the substation. According to the requirement of different parameters, control station will perform its function on the substation. Fig 8 includes functioning of different parameters, which is used in the substation. Along with this if some substations are already running and if another substation is started then its state information is sent to the previously opened substations, this is called peer-to-peer communication i.e. the communication is taking place within the substations. Different substations will be discriminated by their IP address. As in substation 4, the information of new opened substation (5&6) is sent. Through CAST the message is visible on the substation. If load exceeds then LDEXCD parameter becomes active and it will ask substation to shut down. And then the load is balanced by another substation with different IP address. Similarly, the VOLDROP parameter will function. Fig 9, shows a control station and three opened substation i.e. substation 4, 5, and 6. In this way, communication is taking place in between the control station and substations as well as in between the different substation. And this communication between control station and the substations can be seen at the same time on the screen of the system. With this application, the traditional substation can be replaced by new client server model based integrated substation. This communication is based on simple request response protocol. We can drive a new substation communication based protocol that will incorporate the entire requirements of substation specific communication.

TABLE I. List of parameters used in client server model based integrated substation.

SHOW	Running substation
CAST	Sent message to all substation
NUMERIC SUBSTATION	Sent message to particular substation.
LDEXCD	Load exceed in substation balance by another unloaded substation.
TMEXCD	Temperature exceed in substation, adjustment made by an expert.
VOLDROP	Voltage drop, corresponding adjustment made by an expert.
DONE	Decision fixed
HELP	See server command

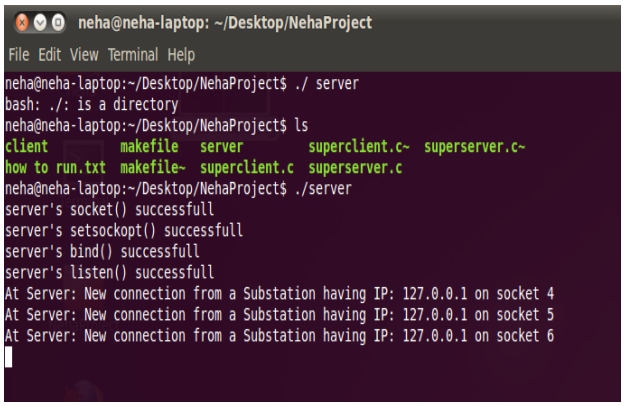

Figure 6. Control station (server) interface displayed with three substation running status.

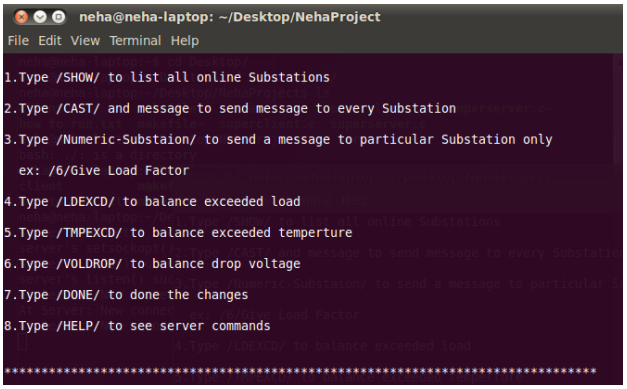

Figure 7. Substation (client) interface when opened then it is displayed with all eight function able parameters.

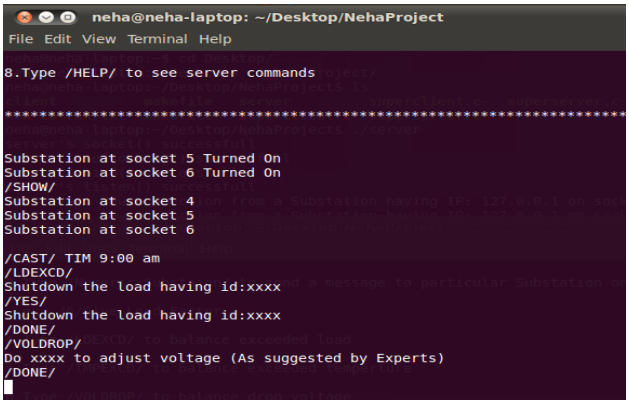

Figure 8. Substation (client) with its different parameters working.

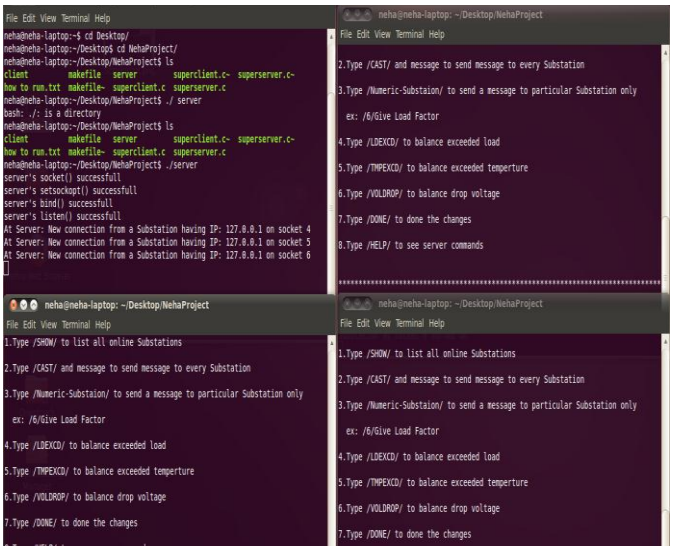

Figure 9. Control station (server) displayed with three running substation (client).

VI. Conclusion

In this paper, we have reviewed the conventional power systems at a typical substation, then the client server based interconnected substation has been presented; a practical case of implementation of digital network substation has been explained. In addition, load balance and fault tolerance has been analyzed.

It includes: -

- It is time saving and reduced constructional cost.
- Saving in the maintenance cost and fault identification and reporting to control station.
- Flexibility, easy to adapt for different installation.
- Integrated data and detail sequence of events can be obtained.
- Handy interface. Entire information of the state of the substation is available at a single location.
- Reduction in space at the control station.

Although the system is very good and outperforms the current state of art, yet there are problems like too many request from the substation (client) to the control station (server) may lead to conjunction problem, which rarely takes place in the peer to peer communication i.e. within substations (client to client), overload can also lead to the breakdown of the control station (server) and if the control station (server) fails, whole network goes down. It is expensive to maintain this type of computing, as it requires IT professionals to maintain the control station (server) and other technical issues.

Also, there is a large scope of optimizing algorithm and protocols that are being used in the current system model. We can improve as well as propose new protocol specific to power substation communication.

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This paper is based on the integrated substations, which are being now replaced by conventional substation. These integrated substations help in effective communication by employing the use of microprocessor technology which has opened a new trend of integrating substation Protection, Control and Data Acquisition (PCADA). In this paper by the use of client server model the communication between different substations can be done by making control station as a server and different substation as client.