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ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 12 (24): 8049-8057, 2013
ISSN 1812-5638 / DOI: 10.3923/itj.2013.8049.8057

Design and Implementation of SCADA System for Micro-grid

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Abstract: The reliability of SCADA system affects the micro-grid operation. The effective design of a Supervisory Control and Data Acquisition (SCADA) system for micro-grid including front-end processing module, communication gateway module and supervisory control module are presented in this study and then the micro-grid SCADA system is built. The actual micro-grid operation tests are performed using the SCADA system. The experimental results show that design and implementation methods of micro-grid SCADA system are practicable and feasible.

Key words: Distributed generation, micro-grid, PV, operation, SCADA

INTRODUCTION

A more flexible and reliable power infrastructure is becoming more and more important due to the tough requirements of society on electricity and its markets and the vulnerability of the interconnected power system to grid failure caused by unexpected natural phenomena which also intensify the burden on traditional electric system. As important supplement for traditional centralized power supply, Distributed Generation (DG) plays a positive role in improving the energy conversion efficiency and power supply reliability (Lasseter, 2002, 2007; Dimeas and Hatziargyriou, 2005; Etemadi *et al*., 2012;Tsikalakis and Hatziargyriou, 2008). DG is located at or near load centers typically, it can be renewable energy resources (PV system, wind power), combined heat and power (CHP, or cogeneration), Reciprocating engine generators and small combustion turbines that run on diesel or natural gas (Nikkhajoei and Lasseter, 2009; Katiraei, 2005; Deng *et al*., 2011).

As a new type of DG network structure, a micro-grid is organized using the DG, energy storage and the local loads and it has two operation modes (1) Grid-connected mode and (2) Autonomous mode (Miller and Ye, 2003; Smith, 2009). The micro-grid can be used to (Deng *et al*., 2013; Palma-Behnke *et al*., 2011; Lasseter *et al*., 2002):

- Provide higher power quality for electronic and other sensitive equipment
- Provide energy or capacity to the utility
- Reactive supply and voltage control from generation.
- System black-start

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A Supervisory Control and Data Acquisition (SCADA) system can be used to monitor and control the devices or equipment in micro-grid, based on computer technology, communications technology and automation technology.Through gathering and analyzing real time data, SCADA system can achieve the supervision and management of micro-grid. Because that the reliability of SCADA system affects the micro-grid safe operation and reasonable dispatch, so, real-time data acquisition and supervisory control are becoming essential(Benghanem and Maafi, 1998; Forero *et al*., 2006).

In this study, a micro-grid SCADA system is proposed and its design and implementation is performed in detail. This studyis structured as follows. Section II outlines the typical architecture of micro-grid SCADA system. Section III describes the design of SCADA system including front-end processing module, communication gateway module and supervisory control module. Section IV presents the implementation of SCADA system for micro-grid and the corresponding experimental results. Conclusions are drawn in Section V.

ARCHITECTURE OF MICRO-GRID SCADA SYSTEM

Micro-grid can be implemented on part of or entire feeders of a distribution substation with facilitating

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large-scale deployment of alternative renewable energy sources, or considered as a constant or controllable load with its real-time control of power generation and consumption, or used for power supply applications in remote communities and nonintegrated areas. The typical architecture of micro-grid is shown in Fig. 1.

The designed micro-grid SCADA system is shown in in Fig. 2, consisting of the front-end processing modules, the communication gateway modules and the supervisory control module. The front-end processing module is responsible for gathering the operation data of DG, energy storage and load devices and control the

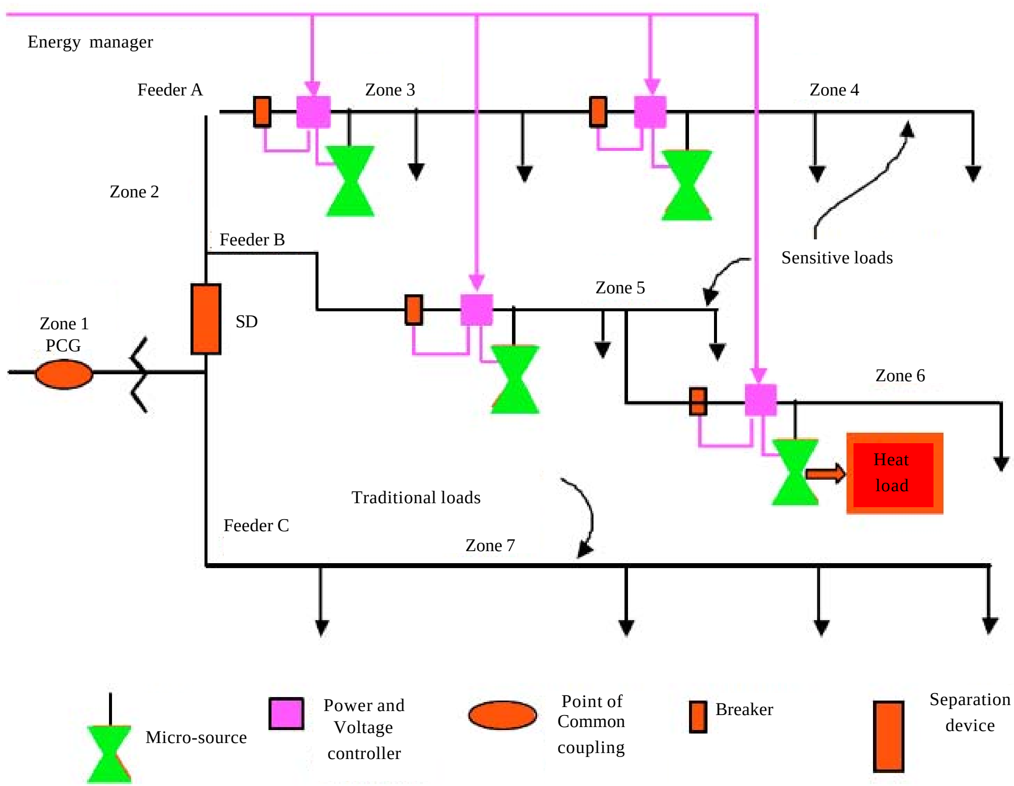

Fig. 1: Schematic diagram of micro-grid

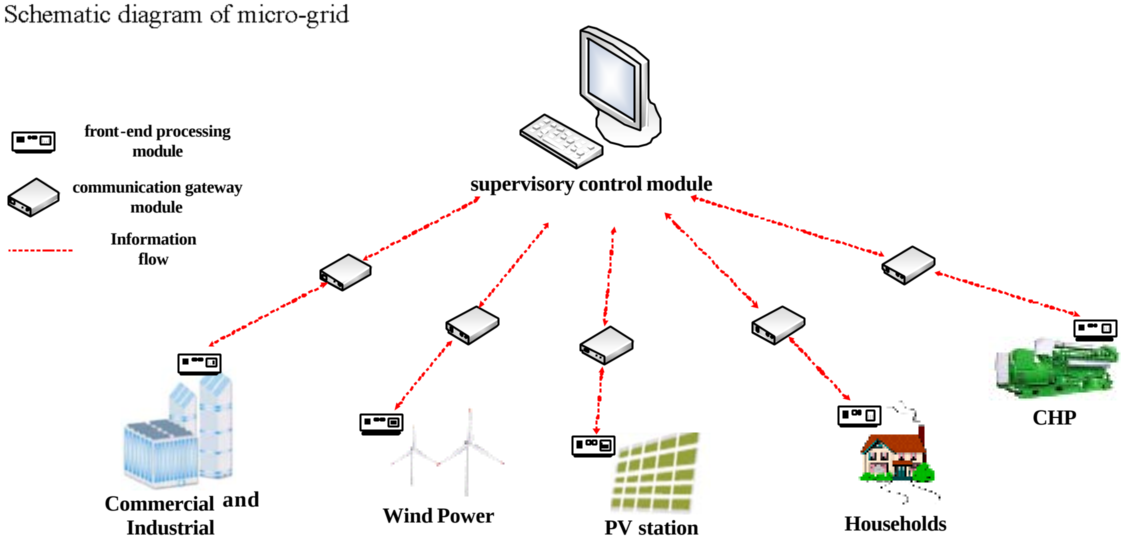

Fig. 2: Micro-grid SCADA system architecture

corresponding devices. The communication gateway module is responsible for the information exchange between the front-end processing module and the supervisory control module. The supervisory control module is responsible for micro-grid advanced analysis and complex decision-making to generate the corresponding controls for system operation.

MICRO-GRID SCADA SYSTEM DESIGN

Front-end processing module: The module needs to periodically gather the status information and the operation data from the DG, energy storage and load devices in micro-grid, with the typical information shown as follow:

- State of Charge (SOC) of battery
- Power consumption of load
- Output voltages of DG
- Output currents of DG
- Charging/discharging current of battery
- System voltage
- Frequency
- Break turn on/off

…

The module should have the AD conversion channel to receive the analog data from the CTs, PTs, etc. The gathered data not only contains the necessary signals butalso includes the noisy signals and errors from AD conversion, so the moduleneeds the signal filtering and modulation circuit. The module should also have the Digital Input (DI) port to obtain the corresponding status information. Considering the control demand. The module should have the Analog Output (AO) port and Digital Output (DO) port to control the actual devices.

The hardware structure of the front-end processing moduleis represented in Fig. 3. The TI TMS320F28335 which is 32-Bit of single-precision floating-pointdigital signal processors, is used as the CPU, with high-performance static CMOS technology and enhanced control and communication peripherals. The sixteen 12-Bit analog-to-digital converters channels can satisfy requirement forhigh-accuracy multiplex signals acquisition. The equipped CAN communication port is used to exchange information with the communication gateway module.

The front-end processing module mainly consists of the data acquisition function by the ADC and DI of DSP and the local devices control function through the DSP AO and DO output, as illustrated in the Fig. 4.

Communication gateway module: The communication gateway module is developed for the micro-grid information exchange. At present, ethernet that has huge and fast data transmissioncapability becomes the common

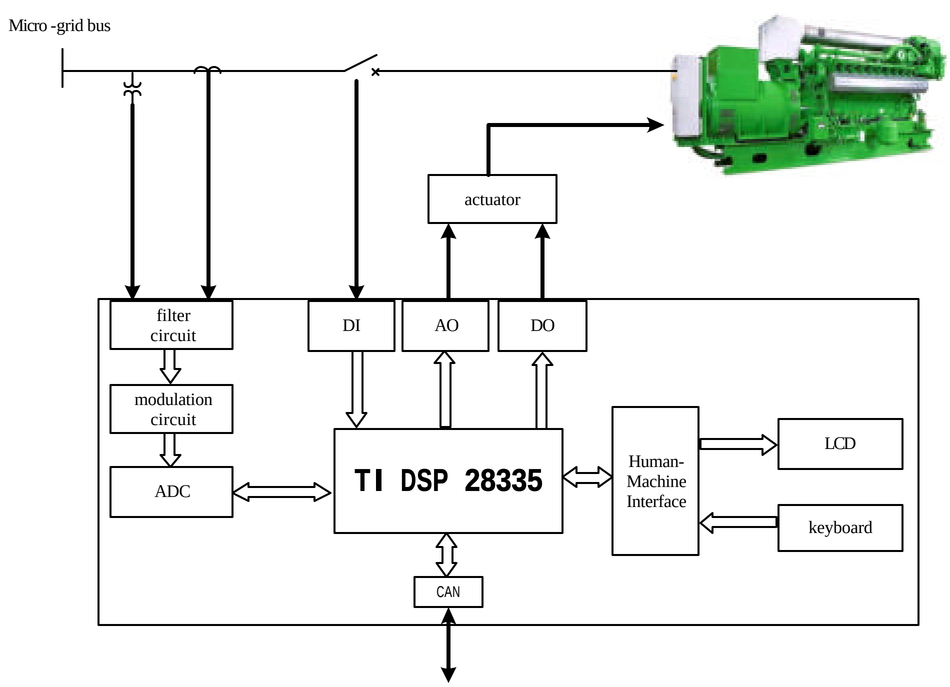

Fig. 3: Hardware of the front-end processing module

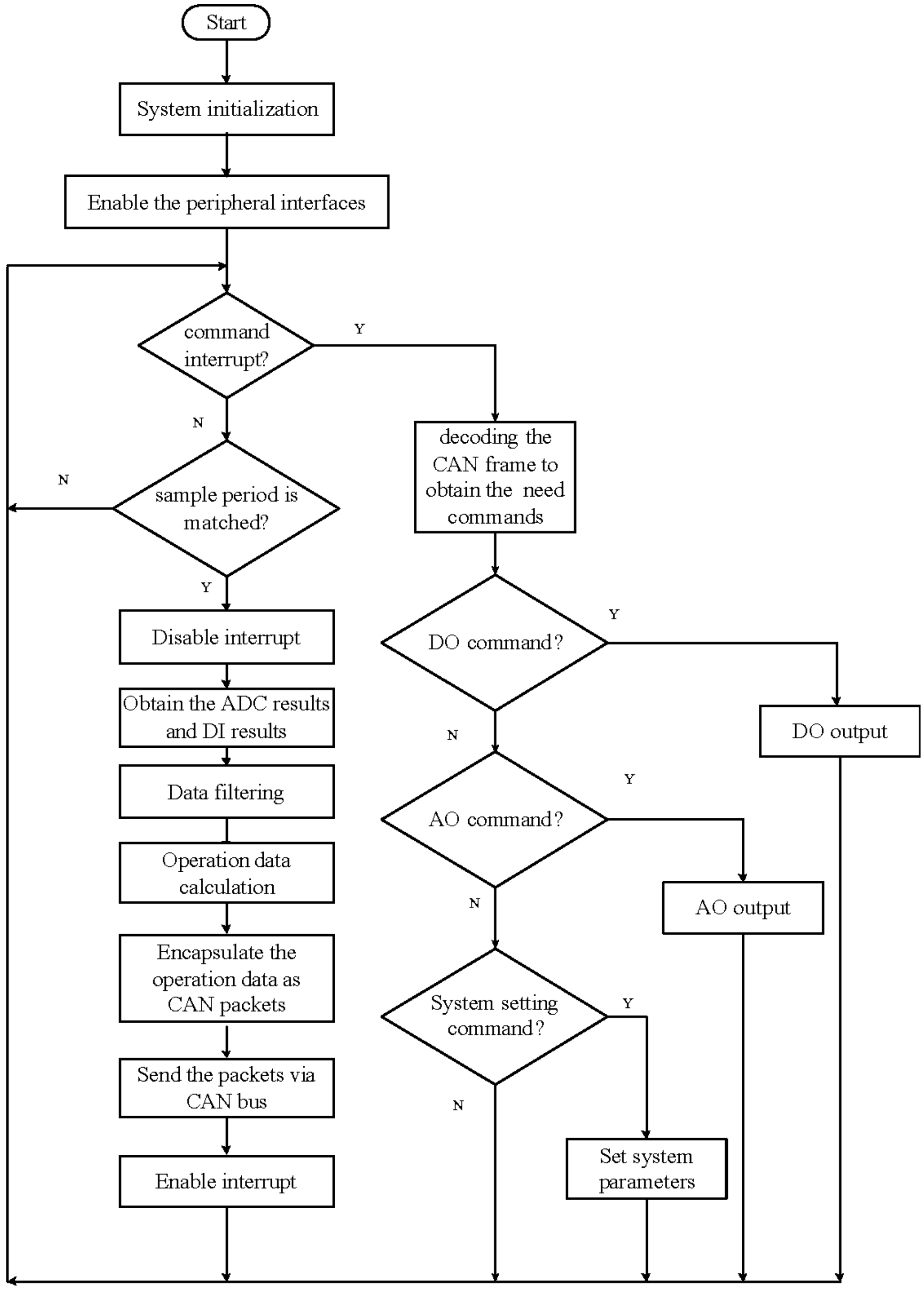

Fig. 4: Front-end processing module workflow flowchart

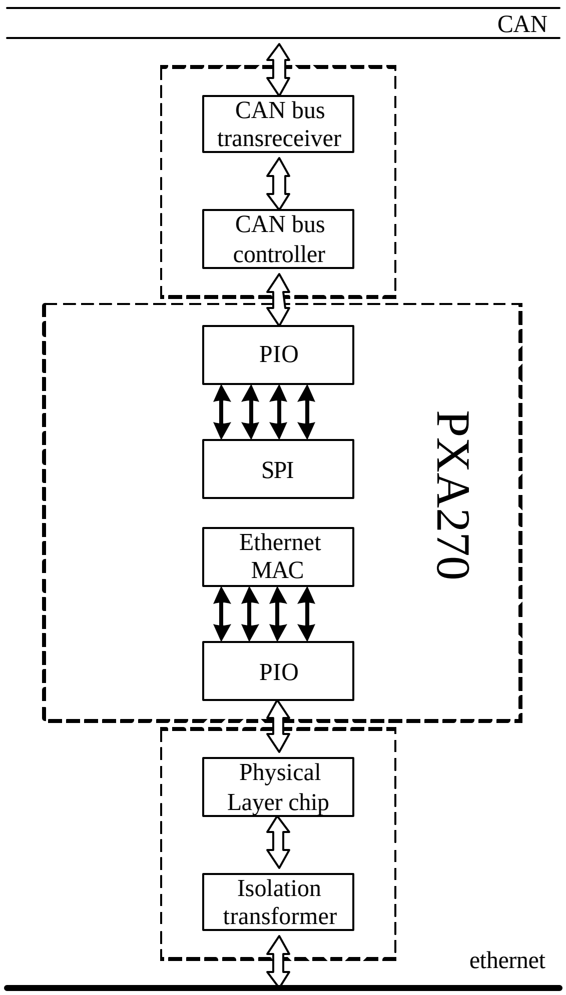

Fig. 5: Hardware of the communication gateway module

networktechnology. The CAN bus is suitable for field network communication in the real-time control systems with high reliability. Therefore, the hardware of the communication gateway module can use the fastethernet and CAN as the main communication interface between the front-end processing module and the supervisorycontrol module.

The protocol conversion is required when the communication networks with different protocolconnect to each other, The Advanced ReducedInstruction Set Computer (RISC) Machine (ARM) processor which has rich extensional peripheralinterfaces and efficientinstruction execution can be used to satisfy the requirement for complete andrapid protocol conversion and real-time multitaskperformance.

The hardware structure of the communication gateway moduleis represented in Fig. 5.

The Marvell® PXA270 processor is used as the CPU which is suitable for a variety of complex electromagnetic environments with the high performance, strong anti- jamming capability, rich peripheral interfaces and low- power consumption. CAN communication and the 100M/1000M adaptive ethernet interface are assembled in the communication gateway module. The ethernet MAC integrated in PXA270 is compatible with IEEE standard 802.3 and it has full-duplex and half-duplex operation mode to realize data exchange according to the data frame format of IEEE standard 802.3

The communication gateway module is responsible for communication connection detection, auto-negotiation, full-duplex and half-duplex operation settings and Cyclic Redundancy Check (CRC). The operation flowchart of the communication gateway module is shown in Fig. 6.

Supervisory control module: The supervisory control module is used to distinguish the micro-grid operation status and correspondingly form the reasonable management strategy and control tasks. Main units of the supervisory control module consist of Data Services Unit (DSU), Advanced Analysis Unit (AAU) and Real-Time Control Unit (RTCU), as shown in Fig. 7.

DSU is used to receive the status information and measured values of micro-grid from the the communication gateway module, transfer the controls and complete the periodical data statistics. AAU is used to assess the present and future opertation status of micro-grid and develop the appropriate system optimization strategies based on the operation data from DSU. RTCU transfer the control information and management tasks generated from AAU to DSU, combining with the control rules. It also feedback the present operation data from DSU to achieve the security check.

The supervisory control module send the controls to the communication gateway module and receive the status information and the measured values from the communication gateway module. The operation flowchart of the supervisory control module is shown in Fig. 8.

MICRO-GRID SCADA SYSTEM IMPLEMENTATION AND OPERATION TEST

The micro-grid SCADA system is developed in accordance with the previously mentioned design of the front-end processing module, the communication gateway module and the supervisory control module. The

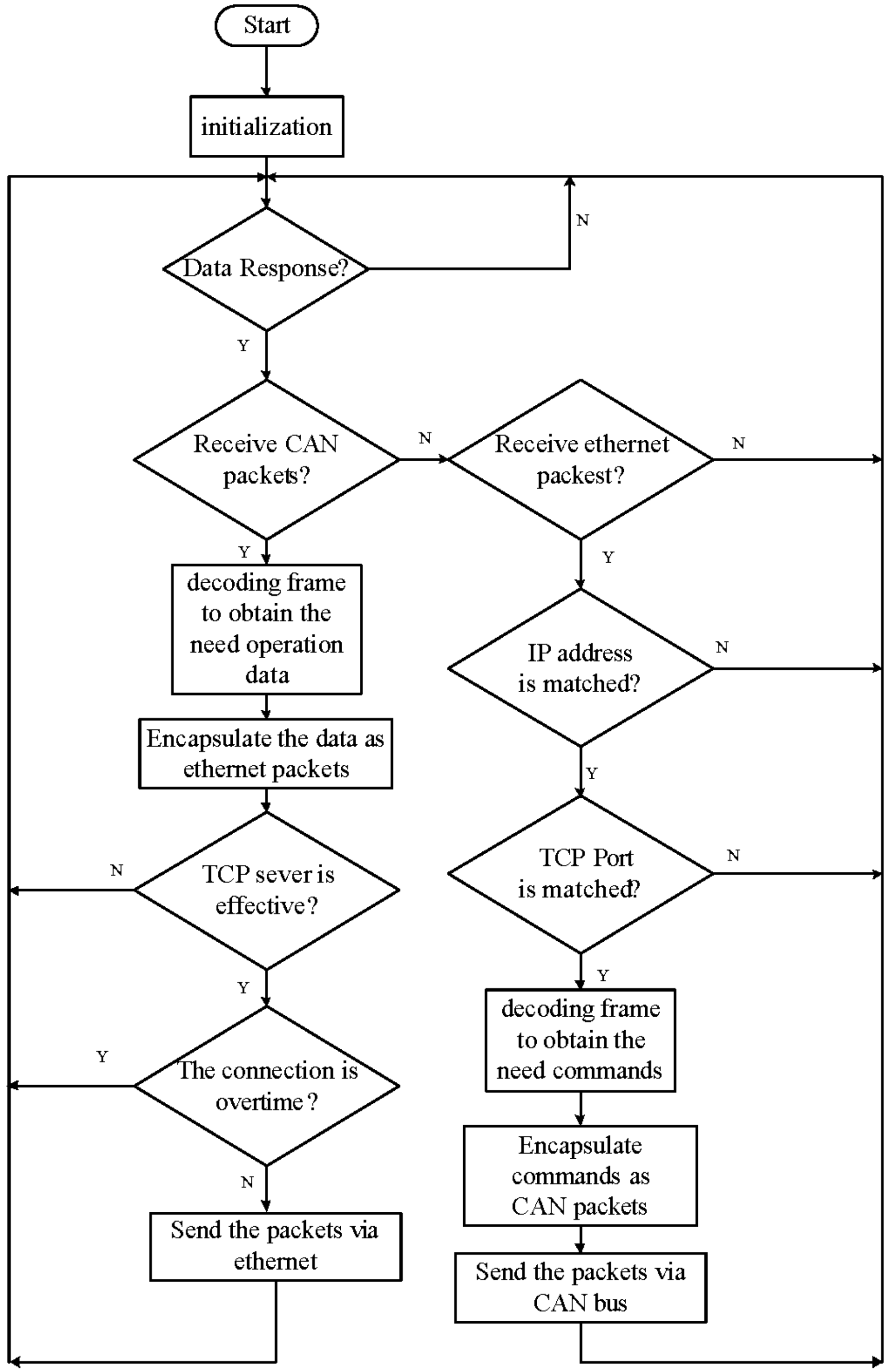

Fig. 6: Protocol conversion flowchart

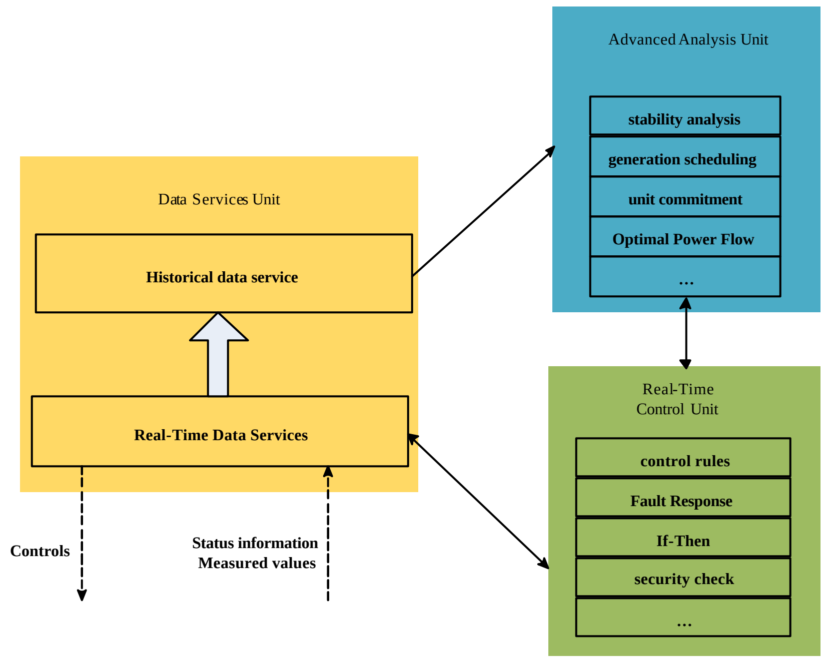

Fig. 7: Structure of the supervisory control module

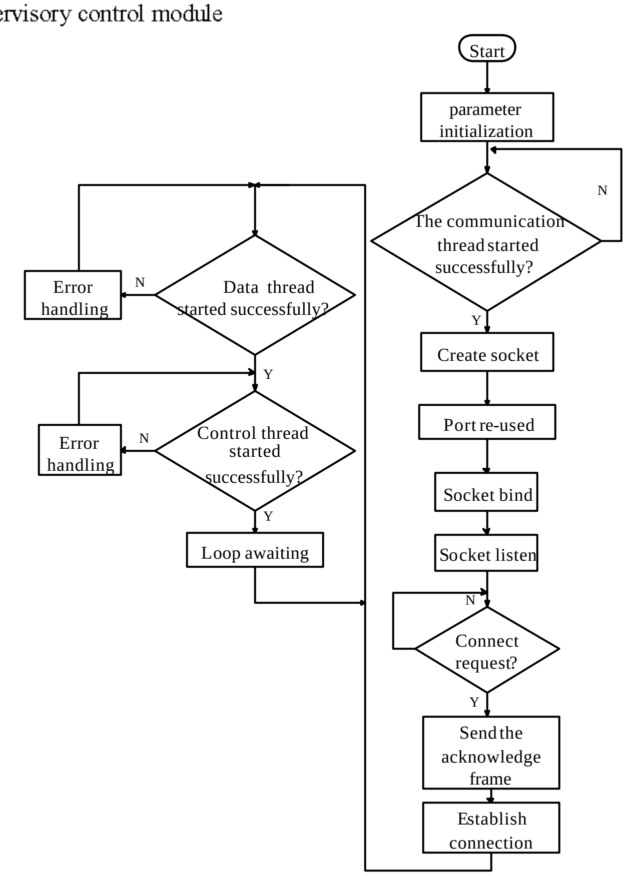

Fig. 8: Flowchart of the supervisory control module

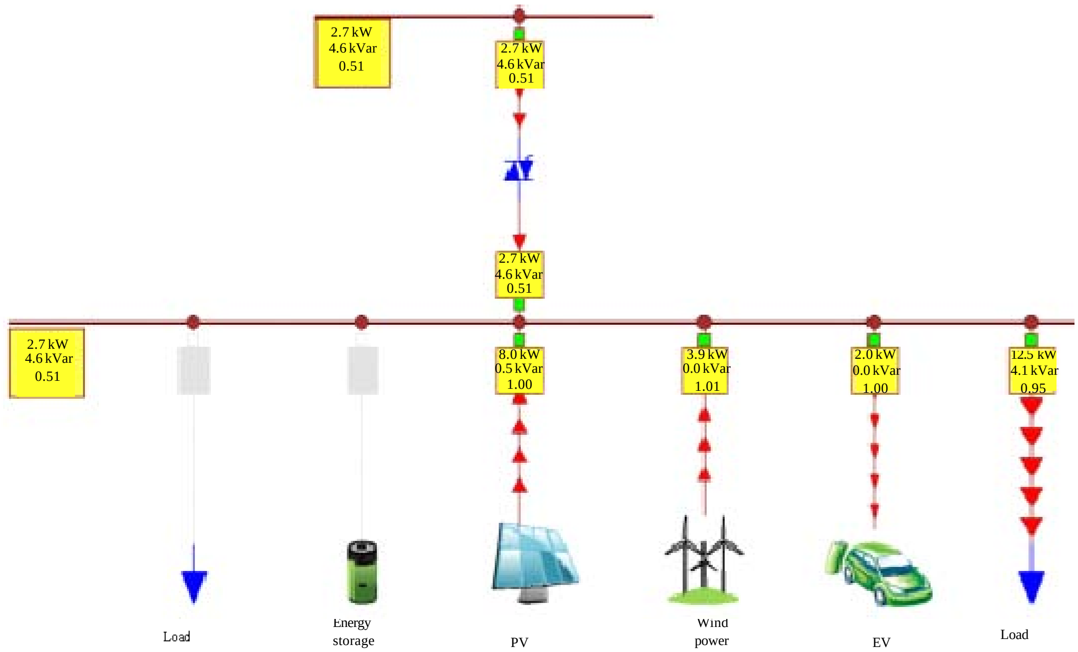

Fig. 9: Micro-grid SCADA system operation test

prototype of the front-end processing module, the communication gateway module are established and the software for the supervisory control module is completed.

As shown in Fig. 9, the micro-grid SCADA system can realize the rapid and safe communication to complete the operation of micro-grid. The front-end processing module can accurately achieve the data acquisition function and the local devices control function. The communication gateway module can completely and reliably exchange information between the the front-end processing module and the the supervisory control module. These monitoring data can accurately reflect the actual micro-grid operation conditions and provide a reliable information source for the advanced analysis and complex decision-making of the supervisory control module.

CONCLUSION

DG is the future power system configuration providing clear economic and environmental benefits compared to power systems. Micro-grid which coordinates types of DG in decentralized way enable DG to provide their full benefits and reducing control burden on the grid. The reliability of SCADA system affects the micro-grid operation. A micro-grid SCADA system including the front-end processing module, the communication gateway module and the supervisory control module is presented. The corresponding operation test based on the developed SCADA system are verified. The research results show that the design and implementation of SCADA system are feasible. It can realize the rapid and accurate information exchange to complete the reliable micro-grid operation.

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