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Real-time Data Acquisition System in Narmada basin – Necessity, Configuration & Advantages

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ABSTRACT

Availability of reliable data such as water levels and rain fall coupled with inflow forecasts for existing/ongoing projects in any basin is essential for taking right decisions on the water management as also for the optimum utilization of water resources. It was in this context, Narmada Water Dispute Tribunal(NWDT) directed under clause XIV of its final orders that, "..... stream and other gauging stations equipped with automatic recorders, wherever necessary, discharge, silt and evaporation observation stations and measuring devices ....." be established, maintained and operated in the Narmada basin. The Tribunal under Sub Clause 8(3)(xvi) also directed that "the Authority shall issue appropriate directions for the establishment, maintenance and operation of an effective system of flood forecasting and flood control, including reporting of heavy precipitation, and telecommunication systems ....". Narmada Control Authority was set up in 1980 as a machinery for monitoring and implementing the final decisions of the Narmada Water Disputes Tribunal for the allocation of Narmada water among the party states of Madhya Pradesh, Gujarat, Maharashtra and Rajasthan. In order to comply with the mandate of the Tribunal, Narmada Control Authority has taken up the implementation of the Hydrometeorlogical network in Narmada basin for the purpose of formulation and dissemination of inflow/flood forecast, water accounting, integrated reservoir regulations including the regulated releases from Indira Sagar Project (ISP) to Sardar Sarovar Project (SSP) for irrigation and other water needs of Gujrat and Rajasthan.

The Real-time Data Acquisition System (RTDAS) being implemented by the Authority through M/s Electronics Corporation of India Ltd. (ECIL) Hyderabad and their foreign associates M/s Vitel Inc. U.S.A. on a turn key basis., is conceptually a fore-runner project in the country in the field of the operational hydrology and has many outstanding features relating to the hydrological and communication aspects, which position it well in the Hi-tech cluster of the country.

In the present paper, an attempt has been made to highlight the need, configuration , potential benefits and challenges confronting this network for the benefit of the user agencies in other basins. The authors are closely associated with this project since its conceptual stage.

NARMADA BASIN

The holy river Narmada, the life-line of the water scarce Malwa and Nimar regions of the central western India, originates from the hills of Amarkantak in Madhya Pradesh. It traverses 1312 km, draining about 99000 sq. km area in the states of Madhya Pradesh, Maharashtra and Gujarat before its outfall into the Arabian sea near Bharuch. The state of Madhya Pradesh is blessed with its first 1077 km. In the next length of 35 Km., the river forms the boundary between the states of Madhya Pradesh and Maharashtra. Again, in the next length of 39 km it forms the boundary between the states of Maharashtra and Gujarat. The last segment of 161 Km. lies in Gujarat, making it a vast interstate surface water system. The planned development of water resources in the basin, comprises of 29 major projects, 135 medium projects and over 3000 minor projects, which altogether shall provide irrigation in an area of 46 lakh ha and generate roundabout 3590 MW of hydel power in the basin. Sardar Sarovar Project in Gujarat is the terminal project among these planned projects. Narmada Control Authority has been set up in 1980 for monitoring and implementing the final decisions of the Narmada Water Disputes Tribunal (NWDT).

NEED FOR THE REAL-TIME DATA ACQUISITION SYSTEM

The present conventional method of manual data observation and transmission results in considerable time lag between data observed in field and its communication to the decision making level which sometimes leaves little time for issuing flood forecast and invoking remedial measures for the dam safety, as also evacuation of population in the downstream flood zone. Thus, the tasks enjoined upon NCA need Hydrometeorological data in real-time environment which can not be met alone by conventional method of manual data observations and communications through HF wireless sets due to the following constraints :

i) Quality of data varying from observer to observer.
ii) Non-uniform maintenance of the timings of data observed in the network.
iii) Susceptibility to the human errors, time lag involved in transmission of data from the point of observations to control room for its analysis, leaving little time particularly for flashy rivers for issue of flood/inflow forecasts.
iv) The system lacks on-line computer compatibility, making the prediction of continuous hydrograph for a number of stations and creation of data bank a virtually tedious exercise.
v) The data communication over wireless telephony is prone to human errors. The network, particularly High Frequency (HF System), is subjected to noises,

interference and black outs particularly during night hours in adverse climatic conditions.

vi) Logistics constraints, particularly at remote stations, make the continuous deployment of staff an uphill task.

The Detailed Project Report (DPR) of the RTDAS network, prepared in 1989 in consultation with CWPRS for Hydrometeorological network, has appropriately envisaged not only the upgradation of some of the existing stations of Central Water Commission and state Governments, but also emphasized the need for the establishment of a Real-time Data Acquisition System equipped with automated sensors, an appropriate communication system and a computerized hydrological forecasting and analysis system comprising of 96 Remote stations and a Master Control station (Central data processing unit) at Indore.

OBJECTIVES

The planned computerized network of 96 Remote stations, operating in real-time environment and free from above mentioned snags of conventional system, shall improve efficacy, accuracy and also warning time round the year for efficient integrated reservoir operation, dam safety and the flood management in the basin which would also facilitate the water accounting and budgeting. It is worth mentioning here that Narmada is the only river basin in the country for which the water account is prepared every water year by the Narmada Control Authority. The planned network is scheduled to be implemented in two phases. The initial phase of implementation comprises of 26 stations spread over the basin and a Master Control Centre at Indore. An index map indicating these stations is placed at Figure-1. The initial phase of the project shall facilitate:

i) Automated real time data communication through Data Relay Transponder of METSAT under 'Interrogation-answer back protocol' at a pre-programmed interval, programmable in the steps of 15 minutes;
ii) Exchange of e-mail within the network.
iii) Inflow forecasts for four reservoirs.
iv) Water level forecast for two important cities in MP.
v) Integrated reservoir operation
vi) Water accounting and budgeting
vii) Creation & maintenance of user friendly hydromet data base for the basin.

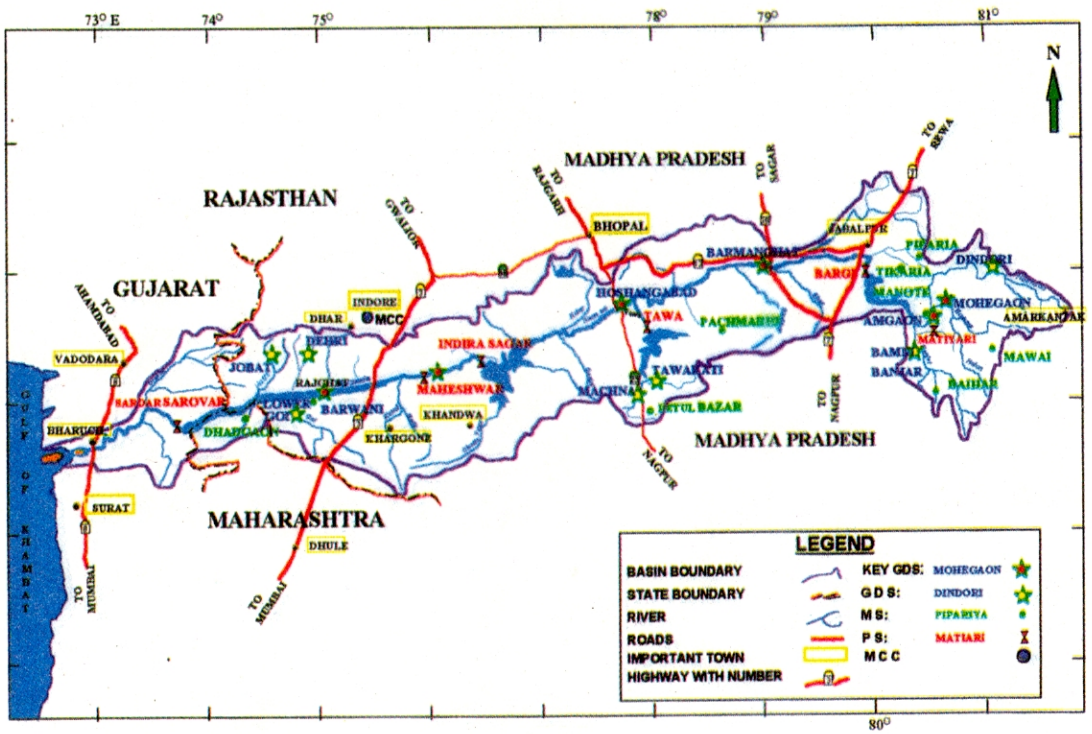

Figure 1. Real Time Data Acquisition System in Narmada Basin

NETWORK CONFIGURATION

The initial phase of twenty six remote stations comprises of eight meteorological stations, thirteen gauge & discharge stations and five project stations. The network is equipped with sensors and Data Collection Platform (DCP) to conduct automatic sensing of hydrometeorological events at various remote stations in the real time mode and the communication of their engineering values through Data Relay Transponder (DRT) on board METSAT to the Master Control Centre, where it is compiled and processed for software modules related to various water management objectives. The network configuration has four sub-systems as follows :-

i) Hydrometeorological sensors
ii) Data Collection Platform (DCP)
iii) Satellite communications
iv) Work station (hub or master control centre)

In addition to above, one more facility for transfer of data through e-mail has also been provided at Key gauge and discharge stations (KGDS) and Project stations.

Hydrometeorological Sensors

The RTDAS network is required to provide data for the eight physical events at the remote stations namely; (i) Rainfall (ii) Wind speed (iii) Wind direction (iv) Relative humidity (v) Ambient temperature (vi) Water level (vii) Evaporation and (viii) Solar radiation, sensed through appropriate hydrometeorological sensors. While the first five of above parameters are observed at each of the stations, KGDS/GDS category of stations do also provide the data for water level whereas the project stations provide data for all the parameters. The sensor is basically a transducer generating the electrical output corresponding to changes in the status/ position of sensing elements owing to physical events. The electrical output of the sensors may be pulse or analog signal, which is fed to the appropriate input channel of Data Collection Platform (DCP).

Considering the range of variation in physical events, accuracy, resolution requirements and DCP compatibility, following types of sensors have been deployed:

i) Rain gauge tipping bucket type (Rainfall)
ii) Anemometer, cup type (Wind speed)
iii) Weather vane, Potentiometer type (Wind direction)
iv) Temperature/Humidity probe, Platinum resistance/capacitance type (Ambient temperature & RH)
v) Optical shaft encoder, float type (Water level)
vi) Evaporimeter, Potentiometer/float type (Evaporation)
vii) Pyranometer, Copper-constantan thermopile type
viii) Pressure transducer type (bubbler) water level sensor for three stations only.

The optical shaft encoder float type water level sensor is housed in a R.C.C. stilling well of 1.5 meter dia / HDPE pipe type stilling well. The ranges of water level variation of GDS & KGDS were finalized on the basis of flood frequency study carried out by NCA, maximum range being 35M. at Barwani. The Pneumatic type water level sensor, which does not require stilling well, has been provided at three stations due to practical constraints in the construction of stilling well. These water level sensors provide the data with a resolution of 5 mm. The local display unit indicates the engineering values of water level, which is converted to the absolute water level by adding it to the set reference level for that station. *Each sensor has its distinct ID codes.*

PJF armoured telecommunication cables are generally used for providing interface between DCP and sensors. However at six stations, line drivers and receivers with cable and at five stations pair of radio modems have been used as interface between DCP and water level sensors due to distance being more than one km. The schematic layout of sensors at a typical project station is placed at Figure 2.

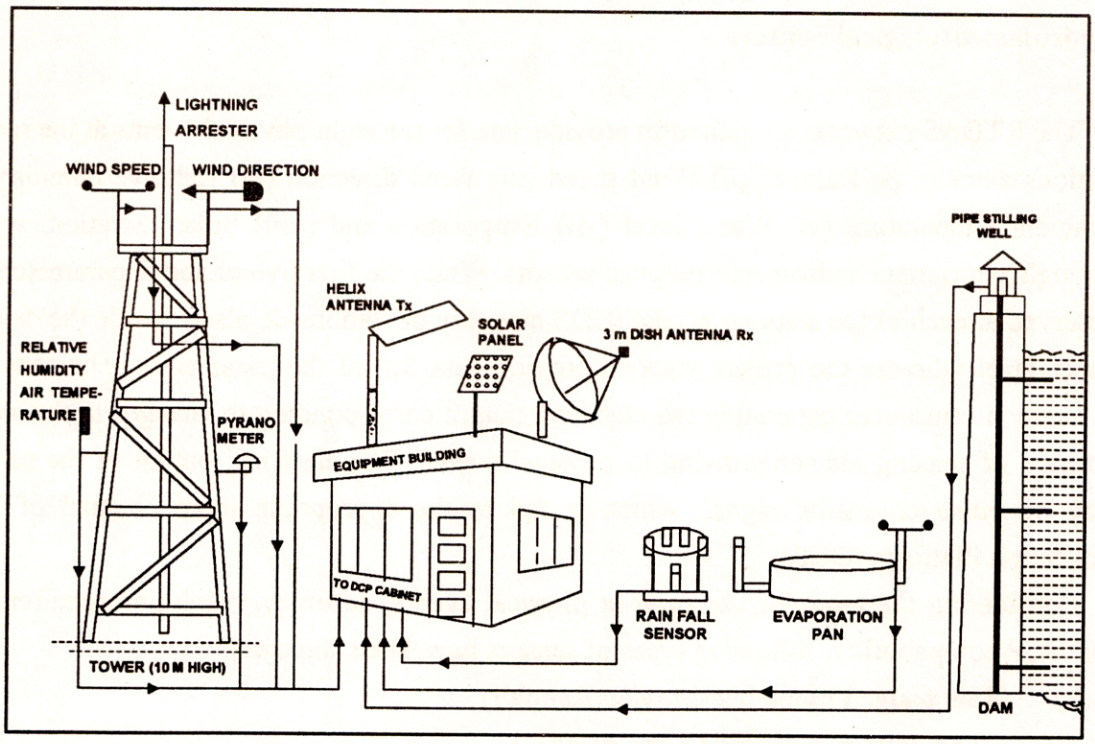

Figure 2. General Layout of Equipments at Project Station

Communication Aspects

The RTDAS network is an interactive data communication system under star configuration by utilizing the DRT on-board METSAT. Prior to launching of METSAT, the network was operating with DRT on board INSAT-2B. The interactive mode operation through DRT makes it not only an unique system being deployed in the country for the first time but also positions it in the select band of few networks of its kind in the world.

The network uses three carriers in the bandwidth of 25 KHz off the assigned center frequency to work as Pilot, Data and Emergency channels. The Pilot transmitter at MCC continuously transmits the carrier for locking up all the receivers of the network at the correct frequency by deploying phase lock technique and thereby enhancing the network reliability even if the satellite is drifting. The network had performed well even when the INSAT-2B had been on an inclination of more than 1.09 degree.

Communication equipment

Data Collection Platform (DCP)

Data Collection Platform, Vitel make VX 1004, is a Type tested, compact, rugged and field proven equipment for global use. This is an insitu intelligent unit, which activates all the functions assigned to a remote station. This is a composite unit of Data Acquisition and UHF transmitter modules having adequate number of analog, digital and SDI input channels to

accommodate all the eight sensor parameters with over 50% redundancy. DCP has the facility of local LCD display of data, RF output and Test message transmission on button pressing. The hardware configuration and the PC plus programme facilitates DCP to perform following tasks:

i) Power supply to sensors at designated voltage;
ii) Conversion of the electrical output of the sensors in to the engineering values;
iii) Data formatting for transmission;
iv) Interrogation-answer back protocol
v) Setting of reference levels/values for the sensors and its setup parameter on command
vi) Local storage of hourly data and text message;
vii) Scanning of sensors at set intervals;
viii) Limited processing of data;
ix) Maintenance of date and time through clock management;
x) Transmitter management;
xi) E-mail operations;
xii) Automated channel shift from the Data channel to emergency channel and vice versa;
xiii) House keeping with the associated INSAT Ground receiver.
xiv) Maintenance of ID for station & sensors

The RF output from the associated RF power amplifier is transmitted through Helix antenna of 10 dBm gain, having the azimuth and elevation corresponding to the orbital parking of METSAT and geo coordinates of the micro earth stations. The data transmission speed is 600 bauds.

INSAT Ground Receiver GR-3000

The INSAT Ground Receiver, Vitel make model GR-3000 in conjunction with mesh type 3.0 M. Dish antenna, LNA, Down converter, Feed, Filter, perform the function of Micro Earth station. The receiver is a modular construction of Input Interface Module (IIM) and Demodulator. The feed down converts the C- band signal from DRT on board METSAT to 77.276 MHz which is further down converted to 5 MHz by IIM for detection by the Demodulator. The detected intelligence is communicated to the DCP for further processing.

E-mail transfers

The network has the facility for the transfer of e-mails of maximum 1800 bytes at one go from one station to the other station including MCC. Industrial grade PC with Printer and UPS with 30 minutes backup have been installed at eleven PS and KGDS category stations.

Even if the PC is in OFF mode, the incoming mail is not lost as it resides in DCP. The transmission of mail from the remote station takes place on emergency channel whereas the Data channel is used for its transmission from MCC. e-mail transfer scheme is depicted in Figure 3.

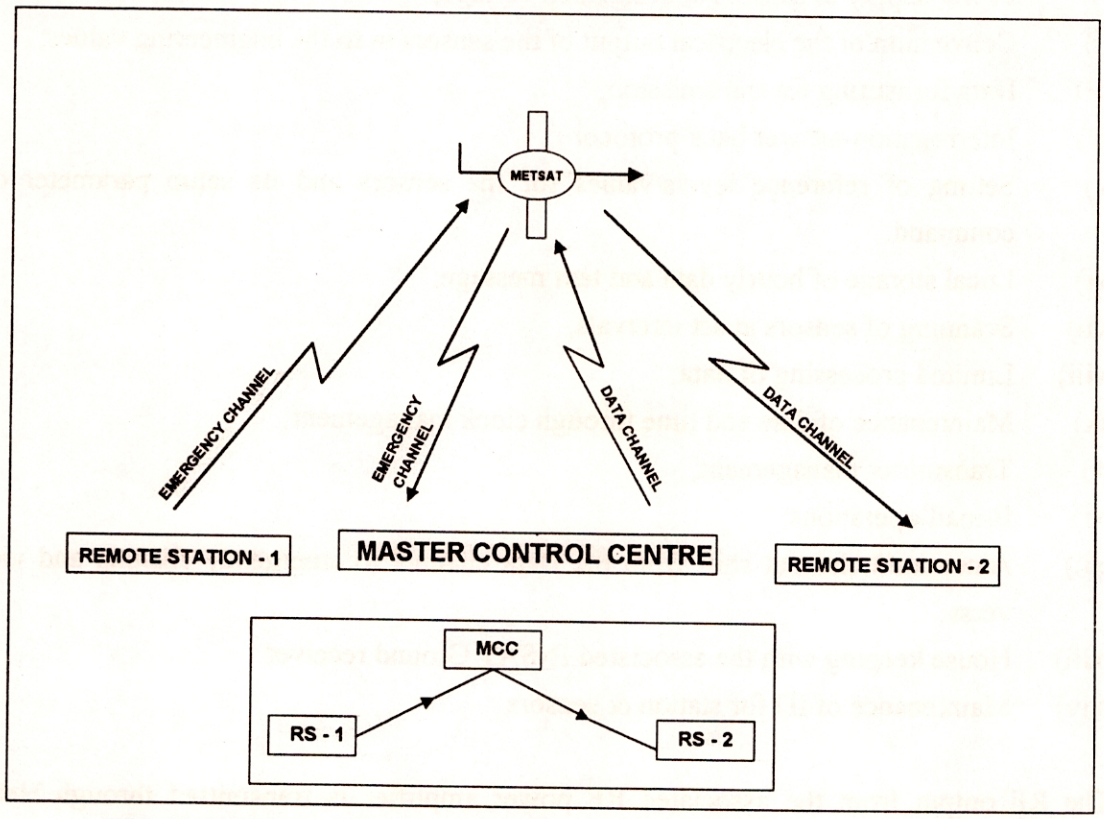

Figure 3. Scheme for e-mail Transfer Between Two Remote Stations

Power supply at the remote station

All the equipments except the Industrial grade PC and printer are supplied with 12 Volt DC power, through two 180 AH 12 volt battery backed by 2 x 72 watt solar panels for charging. The battery capacity is enough to cater to power requirement of the system even without being recharged continuously for seven days. However, to provide additional support system for battery charging, arrangement has been made for AC battery charger-cum-mains power supply unit. In addition, arrangement has also been made for a solar panel backed battery system for radio modems installed on the stilling well. Schematic communication system Block diagram of a typical remote station is indicated in Figure 4.

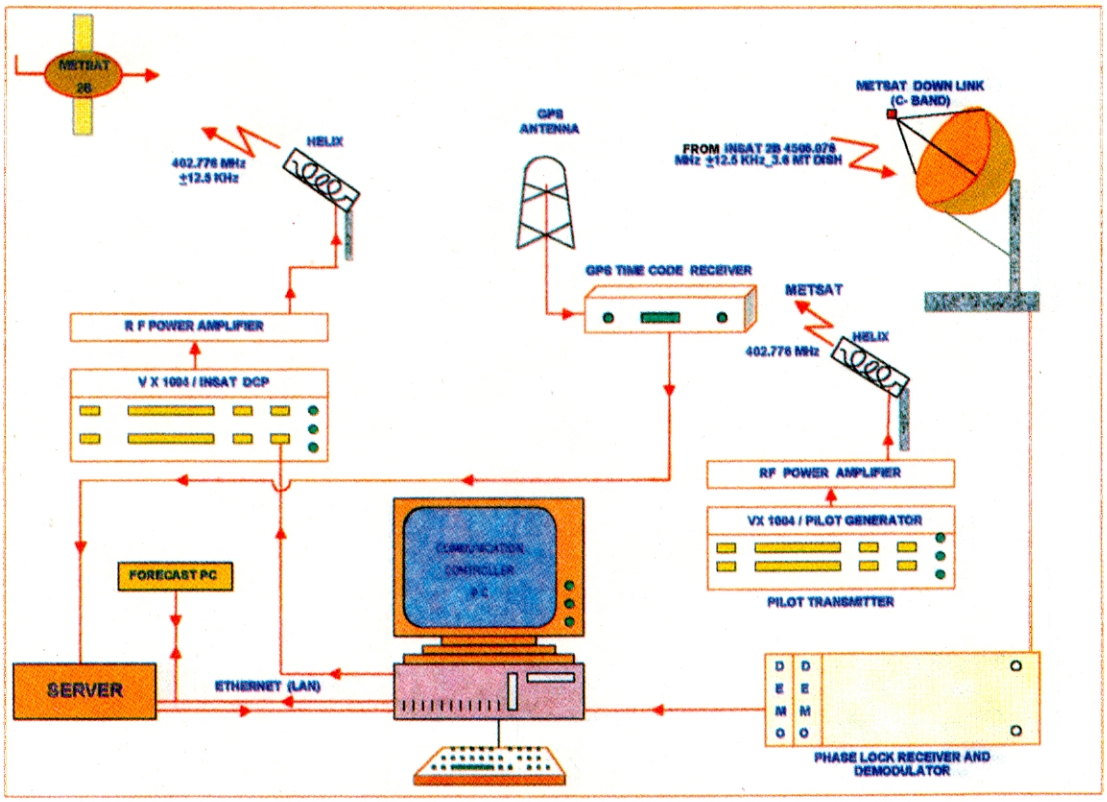

Figure 4. Remote Station Communication System Block Diagram

METSAT: The Communication satellite

The METSAT launched by the Deptt. of Space in the mid of September, 2002 is the smallest Geo-stationary Indian satellite with payload of DRT and VHRR only. The satellite, parked at 74 degree East, has been made operational on 25.9.02. This is a substitute satellite for the abandoned INSAT-2B in respect of DRT. As such, there is no material difference in respect of the characteristics and protocol of DRT of METSAT and INSAT-2B. The DRT bandwidth is 200 KHz off the central frequency of 402.75 MHz. The polarization is RHCP. The downlink frequency is 4.5 GHz in C-band.

Communication System at MCC

The communication system at MCC is the heart of the entire network. The system comprises of Servers, communication controller PC, GR 3000 direct read out INSAT ground receiver, Pilot Transmitter, Data command transmitter and 3.6 metre dish antenna with feeds, LNA, down converter, filter etc. The MCC automatically interrogates each remote station sequentially on its ID address at preprogrammed interval of 60 minutes over the Data channel for communication of the data. It makes three interrogations for a non-responding station before skipping it. The facility for manual interrogation for hourly or instant data also exists.

The time signal is transmitted during the interrogation for the clock synchronization of DCP at remote station for which a GPS time code receiver has been deployed at MCC. The data received are ON LINE transferred asynchronously to the server. 100% redundancy has been provided for each equipment.

The network functions under TCP of 'Datawise' software facilitating the interrogation-answer back feature for single hop long distance telemetry and e-mail requirements. The network has the expandability for more than 150 remote stations and twenty four sensors.

The sensitivity of the system is such that the stations receive the signal at C/N as low as 6 dB. However, for a reliable data communication the threshold level is 10 dB. The schematic communication Block diagram is depicted in Figure 5.

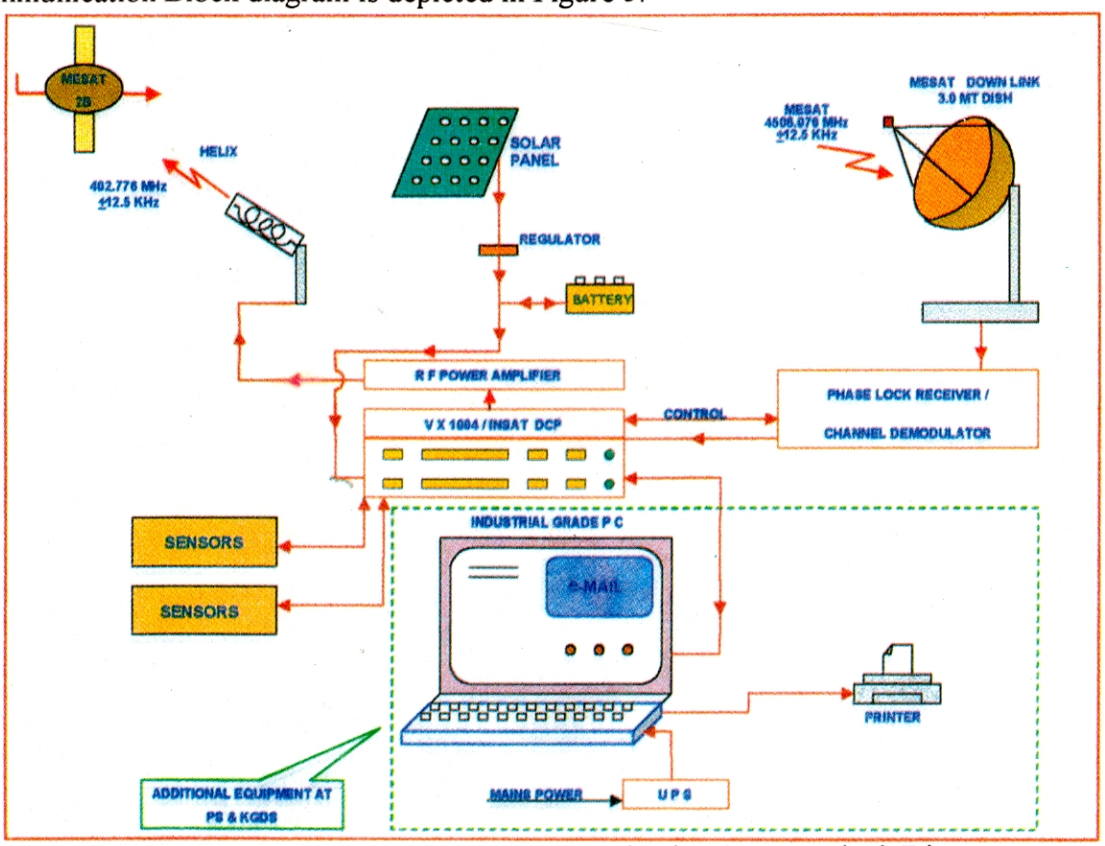

Figure 5. Master Control Centre-Communication System Block Diagram

DATA PROCESSING AT MCC

The data for different events as received at MCC are given in Table 1.

WORK STATION

A dual server and powerful pentium PCs equipped with latest peripherals for graphics, plotter, fast printers, Digitizer etc. are provided on the LAN at the work station for the real

time data management, data validation & processing, catchment simulation, hydrological forecasting for inflow and gauge, integrated reservoir operation, water accounting and dissemination of flood data and warning.

Table 1. Data for Different Events as Received at MCC

i.	Battery	Voltage during the transmission
ii.	Wind speed	Average, Minimum & Maximum during the hour
iii.	Wind direction	Average
iv.	Temperature	Average, Minimum & Maximum during the hour
v.	Relative humidity	Average, Minimum & Maximum during the hour
vi.	Rainfall (cumulative value)	15 minutes interval data of hour
vii.	Water level	15 minutes interval data of hour
viii.	Evaporation	Average
ix.	Surface wind run	Average
x.	Solar radiation	Average, Minimum & Maximum during the hour

SOFTWARE

The application software for RTDAS project comprises of two components which constitute an integral operational part of the entire system network. These components are ; Data Base Management System (DBMS) and Water Management System (WMS). DEC Datawise software package , which is a proprietary DBMS developed by M/s. Vitel Inc, USA serves the functions of a DBMS. This is specially adopted to the needs of the water resources sector. It stores data in two forms, first in a current value table and the second in a historical value table. The Datawise has also been customized so as to be complaint to open data base collectivity (ODBC). The Datawise possesses the capability to process and analyze hydrometerological data from 96 Remote stations. The Datawise is a versatile DBMS containing various software modules.

i) The Water Management System software shall possess the capability to perform the functions of catchment and reservoir simulations, inflow and flood forecast, lean flow assessment and water accounting. For watershed modeling, Sacramento soil moisture accounting model (SSMA) belonging to US National Weather Service River Forecast

System, USA shall be used. HEC-5 in its customized version shall be used for reservoir regulation schedules.

ii) The aforementioned application packages shall be conducted on Windows NT 4.0 operating platform. Windows NT is a user friendly and popular networking operating platform with easy availability of trained personnel and applications.

CONCLUSION

Besides the assigned tasks to be performed by the network as stipulated above, this kind of the network has vast potential to cater to the requirements of the other areas of water resources management However, the sustainable operation of the network faces the challenge, as most of the equipment are imported from the U.S.A.. Therefore, there is an urgent need to indigenously develop the communication equipment and sensors based on such proven technology to minimize our dependence on the foreign associates and their equipment, which may pose spares and maintenance related problems in the long run. The adoption of such kind of cost effective technology needs to be given a serious thought while planning for the inter basin transfer of water and inter linking of river systems in the country in view of its interactive mode of operation which makes it at par with expensive VSAT system and expandability thereof. Data communication in the real time, its instant processing as and when needed, facility to retrieve archival data of any sensor or group of sensors from a centrally located hub are the special features of this kind of network, which a decision making machinery on water resources would always like to relish.

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