

A Novel Direct Method for Generator Sharing Calculation in EMS of Scada Using the Power Division Theorem for Minimum-Loss Real Time Operation

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Abstract: *This paper presents a novel method for directly computing the sharing of each generator in a power system using the Power Division Theorem (PDT) within the Energy Management System (EMS) of Supervisory Control and Data Acquisition SCADA. Real time operational data acquired in actual values are converted into per unit values for load flow and state estimation analysis. Using these normalized quantities, the proposed approach enables immediate estimation of generator contributions to loads and losses at different system levels. The method introduces the concept of Common Source Node Voltage (CSNV) to achieve minimum-loss operation. An illustrative example demonstrates reduced system losses under the proposed constraint. The approach provides a simple and computationally efficient enhancement for real time monitoring and control in modern power systems.*

Keywords: Power Division Theorem; Energy Management System, SCADA, Per Unit System, Generator Power Sharing, Loss Minimization, Common Source Node Voltage, Real Time Operation

1. Introduction

The Energy Management System (EMS) is the brain of SCADA of a Power System. Many analyses are carried out with PU (Normalized) values from actual values at various levels of Power System. The real time operations and control (Load Sharing, Load Shedding and Load Islanding, Load flow, SE etc) are carried out in EMS. [1] Energy sharing, load shedding and islanding schemes performed in EMS by using programmable logic controller with the help of SCADA. Automatic load shedding and islanding scheme is provided to bring the system to a stable operating state under any abnormal condition. The technique is developed based on the magnitude and the rate of change of falling frequency. [2] A feasible Power Sharing technique is proposed for categorizing for all or most type of interconnected micro-grids. The active power sharing between several dispatch able and dispersed generation units in a Micro-Grid (MG) is carried out.[3]. The measured data from SCADA is used for State Estimation (SE) in the conventional method. The deployment of phasor measurement units (PMUs), Advanced metering Infrastructure (AMI), Intelligent Electronic Devices (IEDs) established the unprecedented opportunities for enhancing the performance of SE. This integrates the multiple data sources performance of SE.[4] Effective power-sharing technique for micro-grid was used to operate without a synchronous generator. The converter-interfaced distributed generation (DG) units were also present in the operation. The battery energy storage system (BESS) responds to network changes by the proposed power-sharing technique. The real power output of Each Commercially Distributed Energy Resources (CDER) unit is continuously monitored by a frequency-droop characteristic and a complementary frequency restoration.[5] Cost-based droop schemes is adopted in dispatch-

able inverter-based distributed generators for sharing their power economically in islanded micro-grids. A novel control structure is proposed for the Virtual Synchronous Generator (VSG) that enhances the MG marginal stability, and preserve decentralized economic power sharing. [6] Auto-correction droop control under grid disturbances or sudden changes in local load is used for power-sharing scheme in the Distributed Generators (DG). An improved P-Q-V droop control scheme is proposed to address the shortcomings of the conventional P-Q-V droop control. This achieves proportionally-shared active and reactive powers. It avoids the sudden changes in local load or grid voltage drops. In the existing works, feasible proportional power sharing techniques, frequency-droop characteristic, P-Q-V droop control scheme and cost-based droop schemes are used in EMS to achieve the target of SCADA to certain extent. There is no simple correct powerful way to estimate each generator sharing on each load and losses at the different level of entire Power System during its real time operation. This paper presents a novel method to direct faster estimation of the individual generator sharing. The method uses the PU values in the formula of Power Division Theorem. [7]. The method is validated in the example of a power system given in the book. General Power system diagram is used to illustrate the PDT calculation of generator sharing at different levels by the proposed method for minimum loss.

2. Example

Figure 1. Actual rating of power system components is given Load of 50MVA, 0.8 lagging at 154KV is a particular operating point. The Per Unit values are calculated by selecting 100 MVA Base and 132 Base KV in the transmission line circuit. Figure 2 is the PU diagram with the details of the operating point. The operating point of the

system was determined by solving the equations given in the Figure 3. The PU value of node voltages, load current, generator currents and the powers are shown in the figure2. The total of generator currents IT entering into the network is equal to the Load current IL(Leaving) as shown in the figure. Calculation of each generator sharing of the load by the formula of PDT is displayed in the Table 2. The generators sharing of losses is also given. The PU values are converted to Actual values in all cases by multiplying with Base values as shown in the Table 2.

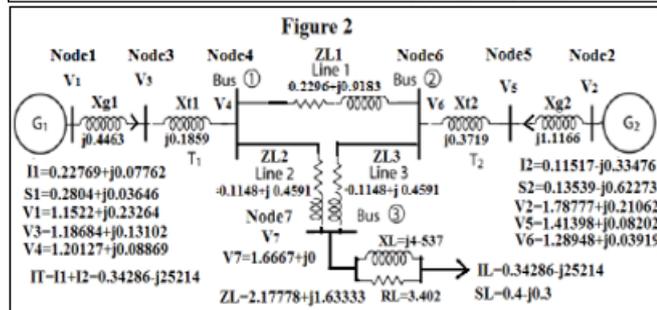
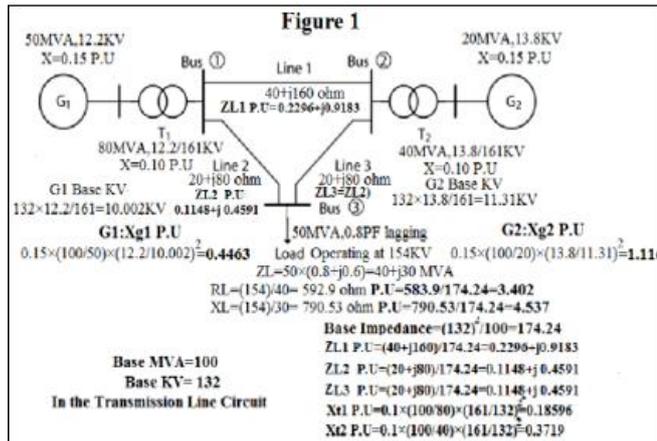


Figure 3

$$\frac{U4 - U7}{ZL2} + \frac{U4 - U6}{ZL1} = i1 \quad \text{---- (1)}$$

$$\frac{U6 - U7}{ZL3} + \frac{U6 - U4}{ZL1} = i2 \quad \text{---- (2)}$$

$$\frac{U4 - U1}{(Xg1 + Xt1)} + \frac{U4 - U6}{ZL1} + \frac{U4 - U7}{ZL2} = 0 \quad \text{---- (3)}$$

$$\frac{U6 - U2}{(Xg2 + Xt2)} + \frac{U6 - U4}{ZL} + \frac{U6 - U7}{ZL2} = 0 \quad \text{---- (4)}$$

$$U1 = U4 + (Xg1 + Xt1) \cdot i1 \quad \text{---- (5)}$$

$$U2 = U6 + (Xg2 + Xt2) \cdot i2 \quad \text{---- (6)}$$

$$i1 + i2 = \frac{U7}{ZL} \quad \text{---- (7)}$$

The operating load voltage at node 7 is already given as 154KV which is $V7=1.6667+j0.0$ PU. Load is also mentioned as 50MVA, 0.8 lagging (0.4-j)0.3). V3, V5 can be found from the solution of the seven equations. Initial guess for I1, I2, V1, V2, V4, V6 is used. The node voltages are shown in the figure 2 and Table 1. The table also displays the actual voltages by multiplying PU values with the corresponding zone Base KV.

Table 1

Node	Per Unit Value	Base KV	Actual Value KV
1	1.1522+j0.23264	10.002	11.52429+j2.32685
2	1.78777+j0.21062	11.31	20.21969+j2.3821
3	1.18684+j0.13102	10.002	11.87078+j1.31047
4	1.20127+j0.08869	132	158.56758+j11.708
5	1.41398+j0.08202	11.31	15.99207+j0.92768
6	1.28948+j0.03919	132	170.2111+j5.17336
7	1.16667+j0.0	132	154+j0.0

G1 Generation $S1=0.2804+j0.03646$ PU, 28.04009+j3.64632
 G2 Generation $S2=0.13539-j0.62723$ PU, 13.5386-j62.72343
 GL1= Generator 1 Sharing of the load 40-j30 MVA
 GL2= Generator 2 Sharing of the load 40-j30 MVA
 GN1=Generator 1 Sharing of the Loss 1.57869-j2862710 MVA
 GN2=Generator 2 Sharing of the Loss 1.57869-j2862710 MVA

The loss in each element is calculated by using the voltage across the element and its impedance. It is verified that the sum of loss in each element is equal to the total network losses 1.578669-j28.62710 given in the Table 2.

Table 2

Sharing of Load and Losses calculated by PDT Base 100 MVA

Generator	Per Unit	Load MVA	LOSS MVA
G1	$GL1=SL \times I1/IT$ 0.26564+j0.09056	26.56378+j9.05556	$GN1 \times BASE$ 1.4763-j5.40924
	$GN1=S1-GL1$ 0.01476-j0.05409		
G2	$GL2=SL \times I2/IT$ 0.13436-j0.39956	13.43622-j39.05556	$GN2 \times BASE$ 0.10239-j23.21786
	$GN2=S2-GL2$ 0.00102-j0.23218		
	$SL=0.4-j0.3$	40-j30	1.57869-j28.62710

Solving the seven equations with the 8 th constraint equation $V1=V2$ reduces the losses to the minimum. Note that in Table3 generator 1 and generator 2 voltages are the same equal to 1.36455+j0.22059PU, but the actual values are different. The novel concept of operating with CSNV for minimum loss was brought out by PDT. Results are shown in the Table 3 and 4. The novel concept is a very important requirement for the EMS of SCADA to reduce the energy consumption during real time operation of the system.

Table 3 Solution with CSNV for Minimum Loss

Node	Per Unit Value	Base KV	Actual Value KV
1	1.36455+j0.22059	10.002	13.64824+j2.20636
2	1.36455+j0.22059	11.31	15.43307+j2.49489
3	1.28929+j0.11789	10.002	12.89547+j1.17916
4	1.25794+j0.07511	132	166.04802+j9.9152
5	1.26572+j0.0947	11.31	14.31534+j1.07107
6	1.23281+j0.05277	132	162.73067+j6.9658
7	1.16667+j0.0	132	154+j0.0

Table 4 Solution with CSNV for Minimum Loss Sharing of Load and Losses calculated by PDT Base 100 MVA

Generator	Per Unit	Load MVA	LOSS MVA
G1	$GL1=SL \times I1/IT$ 0.26846-j0.19674	$GL1 \times BASE$ 26.84643-j19.6742	$GN1 \times BASE$ 0.8336-j8.41312
	$GN1=S1-GL1$ 0.00834-j0.08413		
G2	$GL2=SL \times I2/IT$ 0.13154-j0.10326	$GL2 \times BASE$ 13.15357-j10.3258	$GN2 \times BASE$ 0.27865-j4.23848
	$GN2=S2-GL2$ 0.00279-j0.04238		
	$SL=0.4-j0.3$	40-j30	1.11225-j12.6516

The loss is reduced to **1.11225-j12.6516 MVA**. The reduction in loss is **0.46642-j15.97551MVA** corresponding to **29.55%** reduction in active power loss and **41.93%** reduction in reactive power loss for the same load of 50MVA, 0.8 lagging, operating at 154KV. The general Power System is shown in the Figure 4. All the real time actual values coming from the different levels of the entire system at a particular operating point are converted to PU values in the EMS. The PU representation for the system is in the Figure 4. The Sharing of loads at Transmission, Sub Transmission, Primary and Secondary Distribution Levels can be calculated from the results of the solution of equations with the CSNV constraint $V1=V2=V3$ for minimum loss. The results are in the Figure 4. $Ts1, Ts2$ and $Ts3$ are total share of loads at transmission, Sub Transmussion and primary and Secondary level of the System. $Ns1, Ns2$ and $Ns3$ are net work losses. $TL, TL1$ and $TL2$ are the losses in the Transformers.

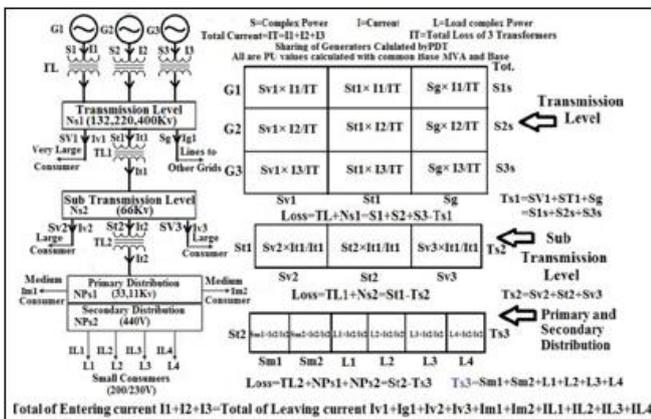


Figure 4: General Power System

The PU current balance for the entire general Power system is shown at the bottom of the Figure 4. Each generator share of any load at any level of the entire Power System can be calculated immediately. As an example, share of generator 2 on the load $Sm1$ at primary and secondary distribution level using PDT as $Sm1 \times Im1/IT$. If this novel method of computation is adopted in the EMS of SCADA of a Power System, faster and best real time control and operation can be achieved.

3. Conclusion

This paper introduced a direct method for computing generator power sharing at various levels of a power system

using the Power Division Theorem within the EMS framework of SCADA. By applying per unit normalization and enforcing a common source node voltage constraint, system losses were reduced in the illustrative example. The approach demonstrates computational simplicity and potential for real time operational enhancement. Future work should focus on large scale validation, integration into commercial EMS platforms, and comparative performance analysis with established power sharing and optimization techniques.

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